FISH HABITAT RESTORATION PLAN

City of Duvall, Washington

Prepared for

City of Duvall Planning Department

December 2002

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City of Duvall, Washington

Prepared for

City of Duvall Planning Department
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Introduction

This restoration plan was prepared for the City of Duvall to improve fish habitat conditions in four streams located within the city's jurisdiction: Thayer Creek, Coe-Clemons Creek, Cherry Creek Tributary A, and Cherry Creek Tributary B. In order to comply with Endangered Species Act (ESA) requirements for protecting habitat for listed fish species, the City of Duvall Planning Department received grant funding to inventory and restore fish habitat in these four streams, which originate in Duvall and are tributaries to the Snoqualmie River. This habitat restoration plan will assist the City of Duvall in securing additional grant funding or encouraging developers to implement restoration projects as a condition for their permits.

Project Location

The four streams that were examined for this project are located in the City of Duvall, in northeast King County, Washington (Figures 1 and 2). These four streams are located in sections 12, 13, and 24; Township 26 North; Range 6 East; and Sections 6, 7, and 18; Township 26 North; Range 7 East (USGS 1968 and 1973).

The restoration area for Thayer Creek extends southeast from its confluence with the Snoqualmie River to its headwaters near Big Rock Road. Figure 3 illustrates the channel configuration and surrounding infrastructure adjacent to Thayer Creek. Coe-Clemons Creek extends east from its confluence with the Snoqualmie River to its headwaters near 275th Avenue NE. Figure 4a illustrates the channel configuration and surrounding infrastructure adjacent to Coe-Clemons Creek. The Cherry Creek Tributary A restoration area extends south from NE Cherry Valley Road to its headwaters near NE 152nd Street. The Cherry Creek Tributary B channel extends south from NE Cherry Valley Road to the northern city limits. Figure 5 illustrates the channel configuration and surrounding infrastructure adjacent to Cherry Creek Tributary A and Tributary B.

Plan Objectives

This restoration plan was prepared for the City of Duvall to evaluate existing fish habitat and to propose restoration projects in the four streams. Specific objectives of this plan are to:

- Identify potential habitat restoration sites based on data collected on limiting factors and habitat needs in these four streams. Describe existing problems and identify appropriate solutions through discussions with the City of Duvall. Such solutions would include stabilizing bank erosion, enhancing the riparian plant community, removing migration barriers, and improving spawning and rearing habitat.

- Collect additional data on selected restoration sites to aid in conceptual design. Research property ownership and access constraints to determine the appropriate construction methods. Collect site-specific data on dimensions of the site, bank and channel slope, riparian plant species composition, and infrastructure conditions.

- Prepare a conceptual restoration plan that presents overall goals and objectives for each stream based on the analysis of limiting factors and habitat needs. This plan also provides preliminary site plans for selected restoration projects that are defined by site-specific goals and objectives, and conceptual designs.

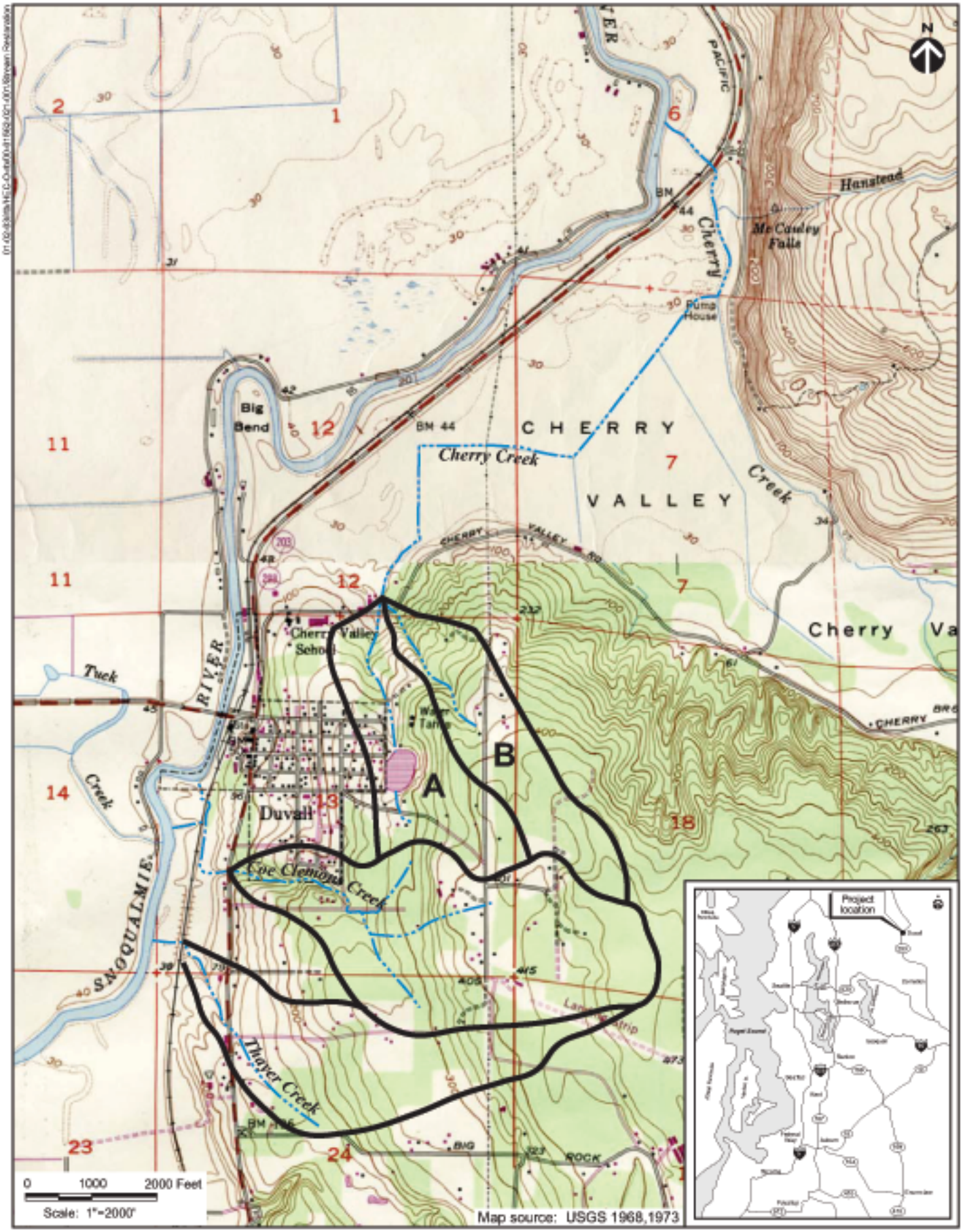

Figure 1. USGS topographic map showing catchment areas for Cherry Creek Tributary A and B, Coe-Clemons Creek and Thayer Creek, Duvall, Washington.

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Figure 2. Location of streams in Duvall, Washington.

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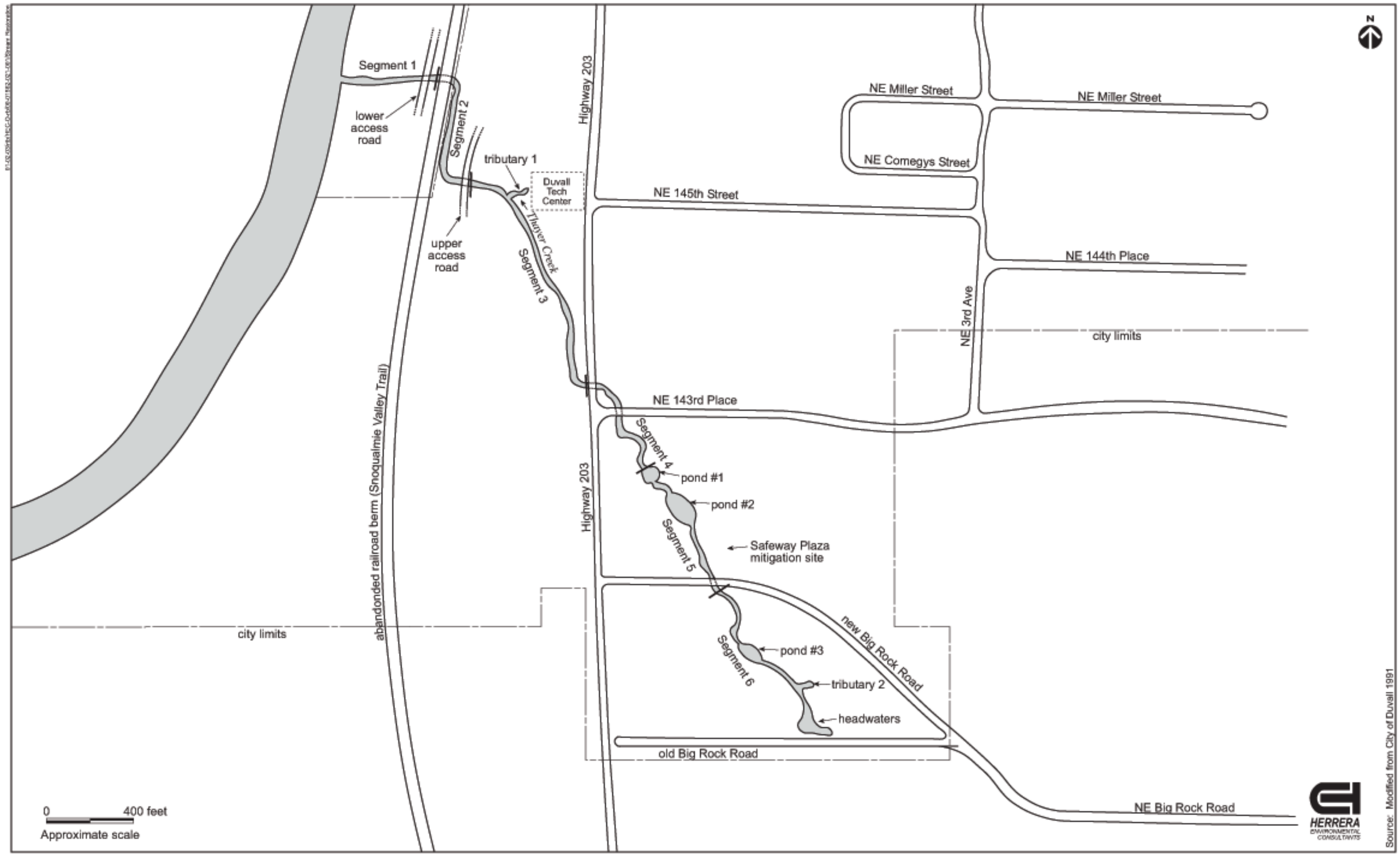

Figure 3. Channel configuration of Thayer Creek within the City of Duvall.

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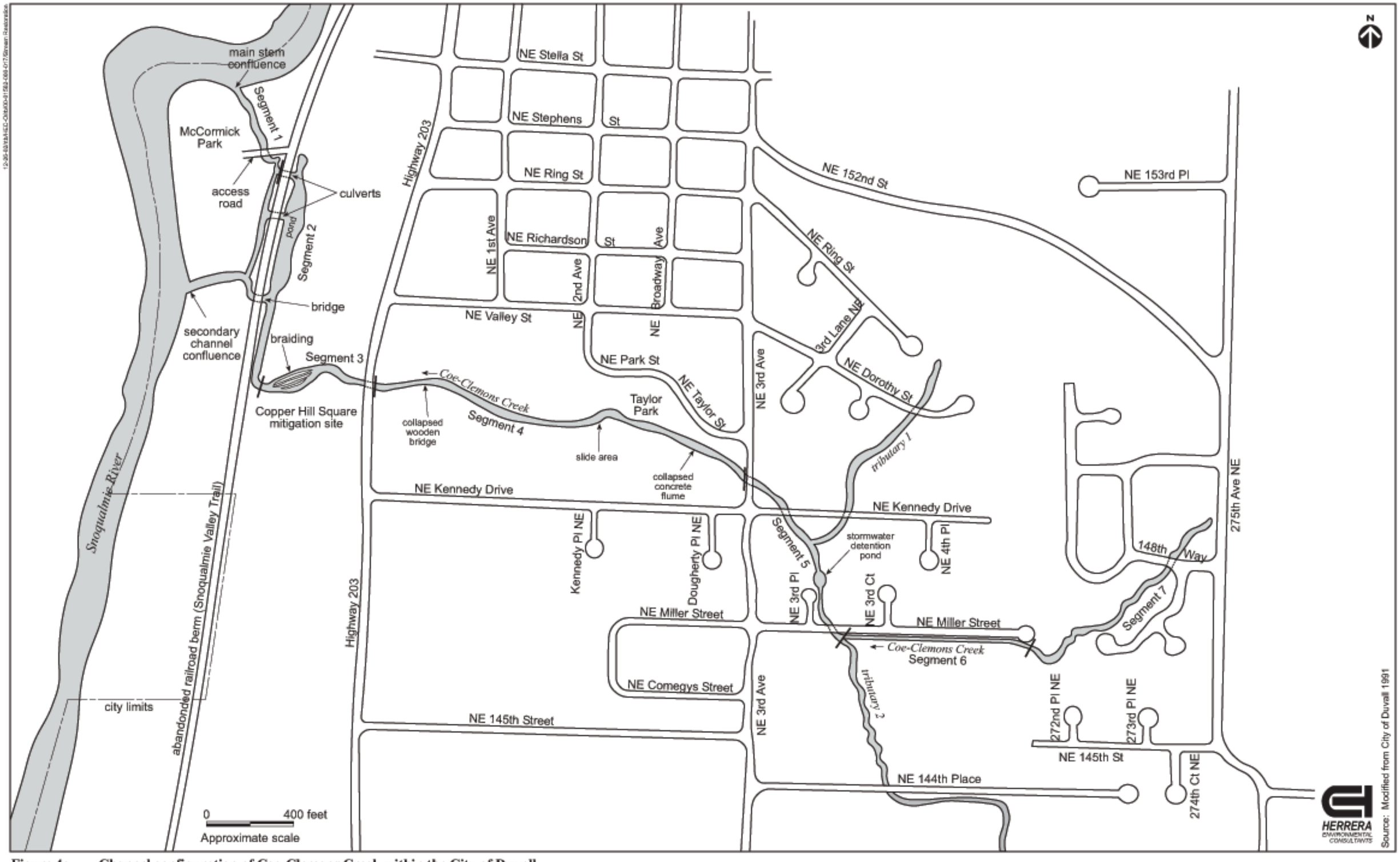

Figure 4a. Channel configuration of Coe-Clemons Creek within the City of Duvall.

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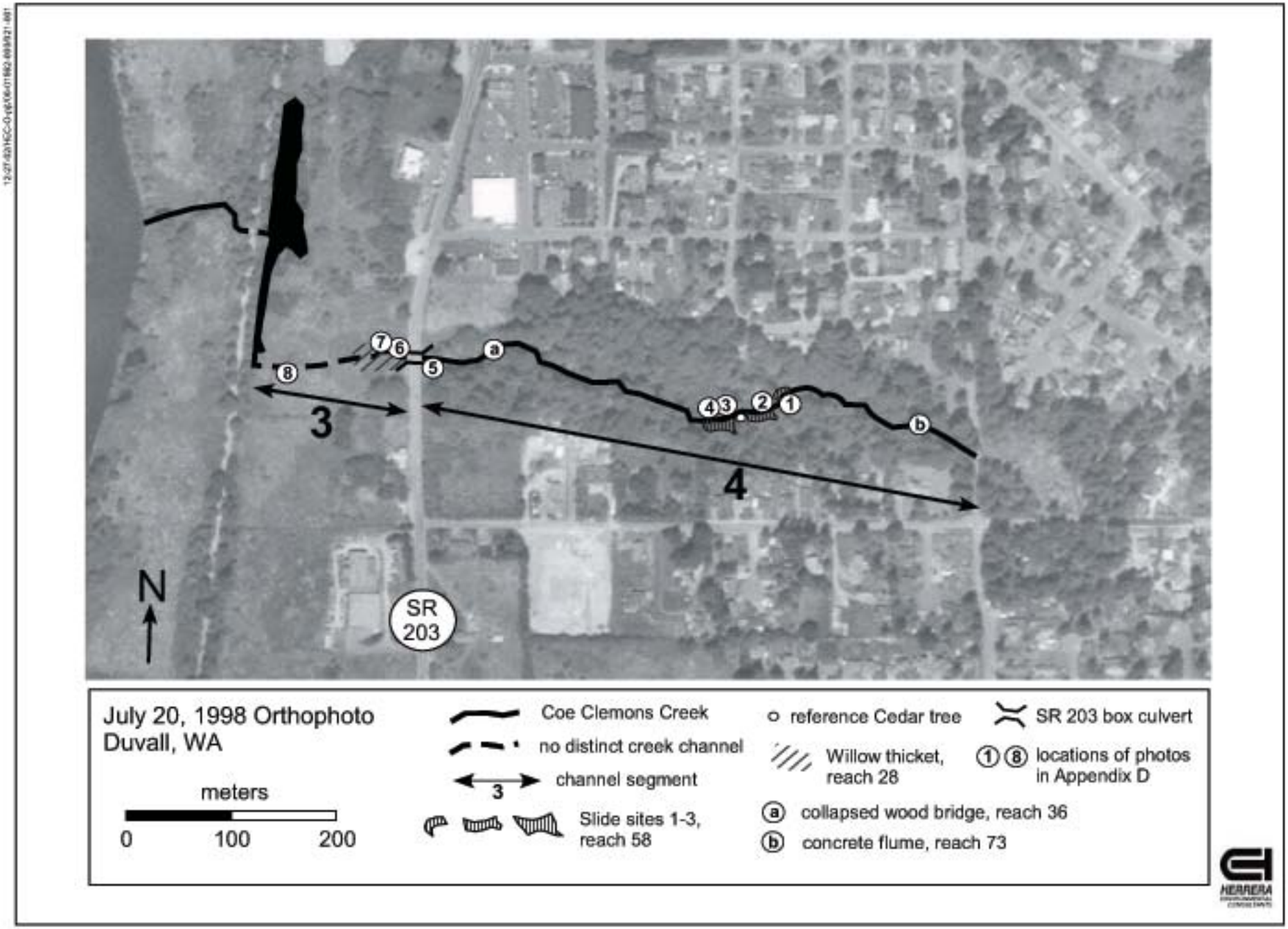

Figure 4b. Coe-Clemons Creek restoration elements in segments 3 and 4.

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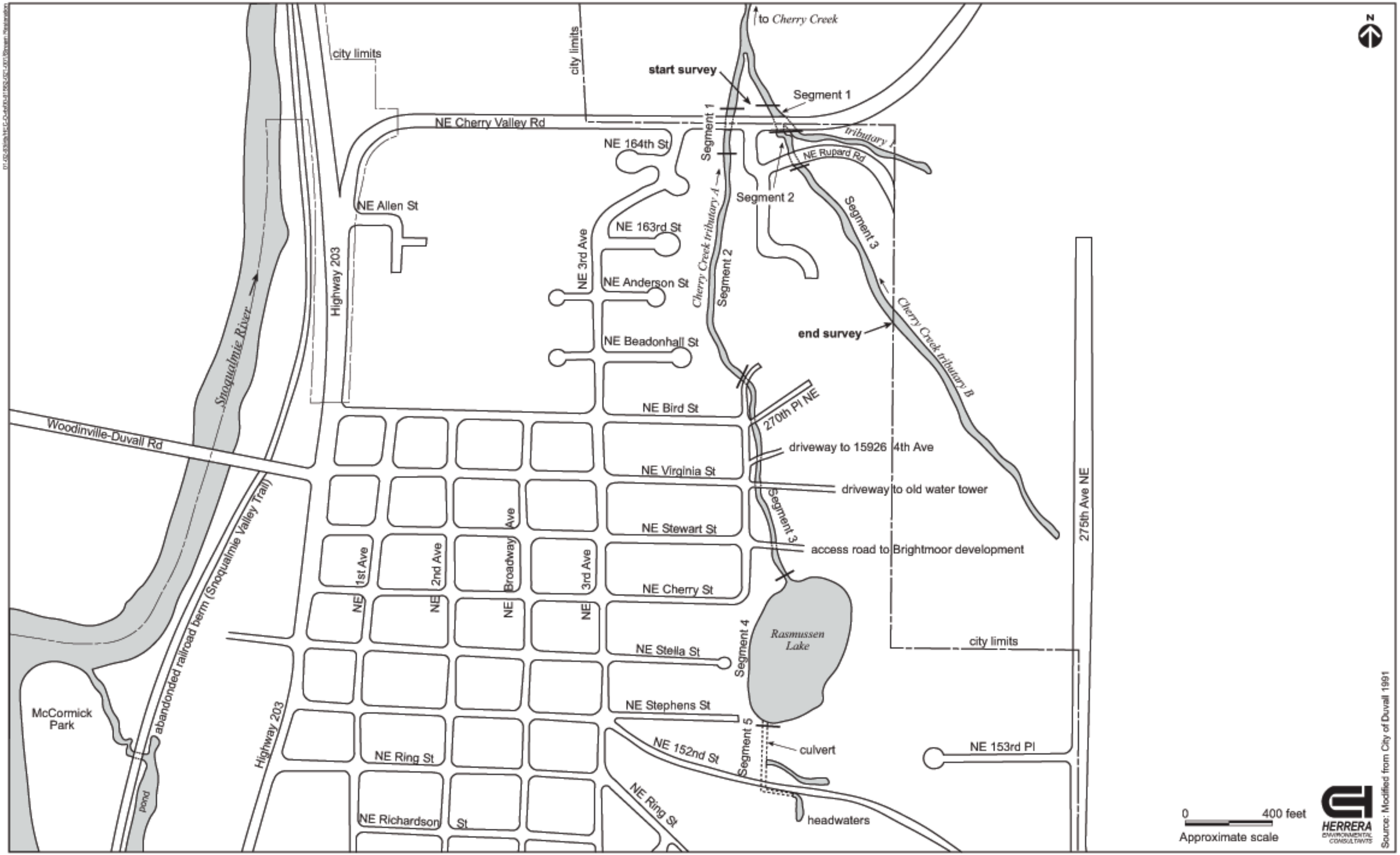

Figure 5. Channel configuration of Cherry Creek tributaries A and B within the City of Duvall.

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Potential Restoration Projects

As a result of past land uses, fish habitat within Thayer Creek, Coe-Clemons Creek, and the two Cherry Creek tributaries has varying levels of degradation. While conducting stream surveys and culvert assessments for this project, biologists often observed poor habitat conditions that potentially could be restored. Such habitat conditions include migration barriers and the lack or poor quality of spawning and rearing habitat.

The following section describes existing conditions and potential restoration projects on Thayer Creek, Coe-Clemons Creek, Cherry Creek Tributary A, and Cherry Creek Tributary B. The creeks were divided into segments and reaches for study. Segments are portions of the creek channel that have similar characteristics such as width, depth, gradient, debris, and vegetative cover. Reaches are portions of the segments that have a definable individual habitat type such as a run, riffle, pool, or chute. Additional information on existing fish habitat conditions in these four streams is provided in *Stream Habitat Assessment for the City of Duvall, Washington—Existing Conditions Report* (Herrera 2002).

Thayer Creek

Table 1 lists potential restoration projects for Thayer Creek. This table describes the project location, the relative priority of each project, and the rationale for selecting each project. These restoration projects are prioritized based on sequential implementation of habitat improvements, from the mouth to the headwaters of the stream (see Figure 3). The top three priority projects are described below.

- Priority 1: Remove migration barriers and improve riparian zone habitat in Segments 1 through 3. The migration barriers include two culverts (access road culvert downstream of the Snoqualmie Valley Trail and the access road culvert upstream of the Snoqualmie Valley Trail), the high-gradient channel in Segment 3, and the incised channel at the Snoqualmie River confluence. Although coho salmon are already accessing spawning habitat in Segment 3, downstream migration barriers are limiting their potential. Enhancing rearing habitat in Segments 1 and 2 will also improve the survival rate of juveniles.

- Priority 2: Remove migration barriers and restore the channel in Segments 4 and 5. The migration barriers include the culverts underneath SR 203 and the berm at the first pond. Removing the berm at the Pond 1 and restoring this area will extend potential spawning habitat up to Pond 2.

- Priority 3: Remove migration barriers and improve rearing habitat in Segments 5 and 6. The migration barriers include the culverts through the berms Pond 2 and Pond 3. Removing these barriers will allow juvenile fish to use rearing habitat in these ponds and in the headwaters.

Table 1. Potential restoration projects in Thayer Creek in Duvall, Washington (see Figure 3).

Segment No.	Reach No. [a]	Potential Restoration Action	Priority	Rationale
1	1-12	Restore Segment 1 by creating a new channel, stabilizing the stream banks, and improving riparian vegetation. This requires excavation to create a wider channel with more sinuosity, and regrading of the stream banks to create 4:1 slopes that are stable during flooding of the Snoqualmie River. Install large woody debris and boulders as bed controls to lower the gradient and to provide juvenile rearing habitat. Plant native tree, shrub, and herbaceous species on the reconfigured stream banks.	3	The incised stream banks and narrow channel in this segment provide poor habitat for adult migration and juvenile rearing.
1	13	Remove 26-inch culvert underneath access road, re-grade the stream banks, and revegetate the disturbed area. This requires excavation to remove the culvert and regrading of the stream banks to create 4:1 slopes. Revegetate the reconfigured stream banks by planting native tree, shrub, and herbaceous species. Replace culvert with truck-bed bridge.	1	This clogged culvert is a partial migration barrier to salmon and acts as a bed control that contributes to downcutting.
2	16-25	Improve riparian zone along stream banks in Segment 2. This requires selectively removing invasive species and planting native tree, shrub, and herbaceous species along the stream banks.	4	Portions of the riparian zone in this segment lack an overstory of trees and shrubs.
2	26	Remove 26-inch culvert underneath access road, re-grade the stream banks, and revegetate the disturbed area. This requires excavation to remove the culvert and regrading of the stream banks. Revegetate the reconfigured stream banks by planting native tree, shrub, and herbaceous species. Replace culvert with truck-bed bridge.	5	This culvert is a partial migration barrier to salmon.
3	33	Stabilize Tributary 1 stream channel between the culvert outfall and main stem. This requires reconfiguring the stream banks to create 4:1 slopes, lining the channel with gravel substrate, and revegetating the reconfigured stream banks by planting native tree, shrub, and herbaceous species.	14	The culvert outfall is eroding the tributary channel and contributing sediment to the main stem.
3	34-44	Provide bed controls to improve adult migration in Segment 3. This requires installing log and boulder weirs in several high-gradient areas where partial migration barriers occur.	2	The stream cascades over existing bed controls, but the gradient is too high and plunge pools are not present.
3	49	Improve riparian vegetation in this reach that is limiting adult spawning and migration. This requires selectively removing invasive species and planting native tree, shrub, and herbaceous species along the stream banks.	7	The channel is clogged by reed canarygrass, which restricts migration through this reach.
4	51	Replace 2-foot culvert underneath SR 203 that is restricting adult migration. This requires excavation to remove the existing culvert and replacing it with a bottomless arch culvert.	6	The slope of this culvert may be a partial migration barrier to adult salmon.

Table 1. Potential restoration projects within Thayer Creek in Duvall, Washington (see Figure3) (continued).

Segment No.	Reach No. [a]	Potential Restoration Action	Priority	Rationale
4	53-55	Enhance riparian zone along stream banks in the pasture between SR 203 and NE 143rd Place. This requires planting native tree, shrub, and herbaceous species along the stream banks.	8	The lack of a forested riparian zone is degrading water quality and limiting juvenile rearing habitat.
4	60-62	Remove riparian vegetation in this reach that is limiting adult spawning and migration. This requires selectively removing shrubs obstructing the stream channel and lining the channel with spawning gravels.	12	The channel is clogged with shrubs that prevent spawning gravel accumulation and restrict migration through this reach.
5	63-66	Remove Pond 1 and restore this area by creating a new channel, stabilizing the stream banks, and improving riparian vegetation. This requires excavation to remove the berm around Pond 1 and creation of a new channel. The elevation differences in this area will require installing bed controls to lower the gradient and regrading the stream banks to create 4**:**1 slopes. Plant native tree, shrub, and herbaceous species on the reconfigured stream banks.	10	The culvert through the Pond #1 berm is a migration barrier; the lack of a forested riparian zone is degrading water quality; and there is no spawning habitat.
5	68	Restore berm that contains Pond 2 by installing a new culvert and filling the trench that breaches the berm. This will require removing the existing obsolete culvert and replacing it with a bottomless arch culvert.	11	The existing culvert and the trench that breaches the berm is a partial migration barrier and is contributing sediment to downstream habitat.
5	70-72	Remove sediment deposits downstream of the Safeway Plaza wetland mitigation site and reline the channel with gravel substrate. This will require selectively excavating sediment deposits interspersed with the existing vegetation and lining the stream channel with gravels.	9	Runoff from the mitigation site has clogged the channel with sediment, which is causing a partial migration barrier and filling in Pond 2.
	78-79	Remove Pond 3 and restore this area by creating a new channel, stabilizing the stream banks, and improving riparian vegetation. This requires excavation to remove the berm around the Pond 3 and creation of a new channel. The elevation differences in this area will require installing bed controls to lower the gradient, and regrading the stream banks to create 4**:**1 slopes. Plant native tree, shrub, and herbaceous species on the reconfigured stream banks.	13	The culvert through the berm is a migration barrier.

[a] Reaches are identified in the City of Duvall GIS Stream Layer.

Coe-Clemons Creek

Table 2 lists potential restoration projects for Coe-Clemons Creek. These projects have been prioritized based on reducing a sediment source and improving habitat, with the highest priority projects located in channel Segments 3 and 4 (see Figures 4a and 4b). Additional restoration actions for the upstream portion of Segment 4 and the creek's upper segments are included as lower priorities. The top five priority actions are described below.

- Priority 1: Reduce sediment supply exported out of channel Segment 4. Eroding hillslopes (slide areas 1-3) in Segment 4 are delivering large quantities of sediment to the creek and degrading downstream habitat. In Segment 4 the creek has sufficient transport capacity to carry the material to the SR 203 culvert and Segment 3, where the material accumulates. Spawning habitat in both Segments 3 and 4 are negatively impacted, and sedimentation in Segment 3 and at the culvert has created fish passage barriers. Sediment supply control in Segment 4 should include grade control structures to dissipate energy and increase sediment storage within the channel and to prevent further incision that has contributed to destabilizing adjacent hillslopes; bank protection along the toe of unstable hillslopes to prevent lateral erosion into the embankments and improve habitat by adding boundary roughness; and planting of native tree species to stabilize hillslopes.

- Priority 2: Remove migration barriers and improve habitat between Segments 3 and 4 and through Segment 3. The SR 203 culvert is currently nearly filled with sediment and presents a potential migration barrier. An immediate solution includes the removal of accumulated sediment in the culvert and portions of the Segment 3 channel. A more sustainable solution may be to replace the existing culvert with a larger culvert or bridge that that ensures fish passage and sediment conveyance despite a fluctuating streambed.

- Priority 3: Construct a new channel for lower Coe-Clemons Creek (Segments 1-3) that connects Snoqualmie River to SR 203 and provides grade control and sediment transport capacity. Existing channel blockages limiting conveyance and fish passage will have to be removed. The channel migration zone and riparian areas of Segments 1-3 should be planted with large native trees (red alder, black cottonwood, and red cedar).

- Priority 4: Remove migration barriers in Segments 4 and 5 to allow adult salmon to access spawning habitat near the headwaters. These migration barriers include a collapsed wooden bridge and a concrete flume in

Table 2. Potential restoration projects within Coe-Clemons Creek in Duvall, Washington (see Figures 4a and 4b, reaches in GIS database).

Segment No.	Reach No. [a]	Potential Restoration Action	Priority	Rationale
1	1-2	Stabilize stream banks, improve juvenile rearing habitat along channel boundaries, and re-establish native riparian vegetation. Install large woody debris as bed controls to lower the gradient and provide juvenile rearing habitat.	6	The incised stream banks in this segment provide poor habitat for adult migration and juvenile rearing.
1	7-9	Improve fish passage through the culvert beneath the access road into McCormick Park. This requires removing quarry spalls at the culvert inlet and outlet and creating a holding pool at the culvert outlet.	8	Adult migration through this culvert could be enhanced by presence of a resting pool at the culvert outlet.
2	11	Replace the culvert underneath Snoqualmie Valley Trail (SVT) that is restricting adult migration. This requires excavation to remove the existing culvert and replacing it with a bottomless arch culvert.	7	The current culvert is small and has been blocked by beavers to impound the creek upstream of the SVT. A larger bottomless culvert would allow bed adjustment and better maintain fish passage.
3	14-28	Design a new channel graded between downstream SVT crossing and upstream SR 203 crossing. Bury snags in and along new channel to create local flow deflectors to sustain pools and provide cover. Excavation will be required to construct new channel. Excavated fill will be used to create floodplain hummocks for native conifers. Establish native riparian forest on floodplain and channel migration zone (CMZ) throughout the length of Segment 3.	3	Sediment from a slump upstream of this area has clogged the channel, which is causing a partial migration barrier. The channel is clogged by sediment and reed canarygrass, which restricts migration through this reach. Active channels aggrade rapidly and spread out in sheet flow through the reed canarygrass. Forest conditions will help limit reed canarygrass and maintain aquatic habitat, particularly when new channels form
3	28	Improve conveyance through SR 203 crossing. An immediate solution includes excavating sediment in the culvert and channel upstream and downstream of culvert (i.e., bucket drag line). Stabilize excavated channel banks upstream and downstream of culvert. For a sustainable solution, replace the culvert underneath SR 203 with either a new culvert (large bottomless arch) or bridge.	2	Channel aggradation in Segment 3 and the concrete box culvert beneath SR 203 have created a barrier to fish migration and degraded aquatic habitat. The culvert currently has only 6 inches of clearance and probably causes significant backwater during high flows. The culvert is at risk of completely plugging with wood debris and sediment, a condition that would effectively cut off flow to lower segments of the creek and impound Coe-Clemons Creek. This condition would also pose potentially catastrophic risks to the SR 203 embankment requiring emergency actions that could further impact habitat.

Table 2. Potential restoration projects within Coe-Clemons Creek in the City of Duvall (see Figures 4a and 4b, reaches in GIS database) (continued).

Segment No.	Reach No. [a]	Potential Restoration Action	Priority	Rationale
4	36	Improve fish passage through reach 36 by removing artificial obstructions and constructing new channel in which head loss is accommodated over complex multi-log weirs. Pieces of collapsed wooden bridge should only be removed if necessary, otherwise they can be re-located on site and incorporated into new channel and floodplain. New channel design must ensure that sediment and wood debris currently stored at site is stabilized and not released, particularly given the close proximity to the SR 203 crossing.	4	Fish migration is currently restricted where the channel has become clogged where an old wooden bridge collapsed into the creek and collected deposits of wood debris and sediment.
4	58	Reduce the quantity of sediment exported from Segment 4, focusing on reach 58 where 3 landslide sites are delivering large quantities of sediment to creek. This strategy includes three elements: 1) design and place complex multi-log grade control structures to prevent further incision destabilizing hillslopes, trap sediment, and improve habitat and fish passage, 2) design and place snags to protect toe of adjacent hillslopes, and 3) grade and terrace over-steepened slide areas and revegetate slopes with young native conifers, dogwood cuttings, ferns, and salmon berry. Use tree trunks where terracing is appropriate. Where possible, grade control will raise creek bed above clay unit underlying glacial tills.	1	Three landslide sites have delivered approximately 2600 cubic yards of sediment to creek. Hillslopes are composed of highly erodible glacial tills (consisting primarily of sand and silt interspersed with deposits of poorly sorted gravel and larger clasts). Till is underlain by impermeable clays that form a barrier to infiltration and a shear plane. Slides have been exacerbated by increased peak flows, channel incision at toe, sparse tree cover on hillslopes, and seepage from above. The slide material has moved down the creek and contributed to aggradation in SR 203 culvert and Segment 3 that has degraded fish habitat and inhibited migration.
4	70-72	Install erosion protection along banks where creek is cutting into clay unit using snags and logs in channel and at toe of banks.	14	Erosion of the clay layer is degrading habitat by contributing fine-grained sediment which infiltrates spawning gravels.
4	73	Remove or re-arrange pieces of concrete flume and align channel as appropriate to allow for adult migration. Ensure that grade control is in place to prevent incision and release of stored sediments.	5	Portions of a concrete flume situated in the creek have trapped sediment and is clogging the channel and restricting fish migration through reach 73.
5	76	Improve fish passage through the culvert underneath NE Third Avenue by removing a log from the culvert outlet. Install a hydraulic step at culvert under NE Kennedy Drive using logs or boulders to create a plunge pool for migrating adults and juvenile refugia.	9	The culvert is currently a migration barrier to fish using upstream habitat.

Table 2. Potential restoration projects within Coe-Clemons Creek in the City of Duvall (see Figures 4a and 4b, reaches in GIS database) (continued).

Segment No.	Reach No. [a]	Potential Restoration Action	Priority	Rationale
5	88-90	Improve conditions for fish passage by constructing hydraulic steps below outlet of culverts draining stormwater detention pond near NE Third Place using logs or boulders to create resting pools for migrating adults.	10	Culverts draining stormwater detention pond currently inhibit fish migration to upstream reaches.
5	92	Improve fish passage through the culvert near NE Third Place by constructing grade control structures of logs or boulders to reducing water velocities at the culvert inlet and create holding pools where possible.	11	Absence of a resting pool at culvert outlet inhibits adult migration.
5	98	Improve fish passage through the culverts underneath Miller Street by reducing water velocities at the culvert inlet. This will require installing large woody debris and boulders as bed controls to create a resting pool at the culvert inlet.	12	Adult migration is inhibited by high velocities at culvert inlet and lack of resting pools.
6	100-135	Improve fish passage through the 12 culverts underneath private driveways along NE Miller Street. This will require installing grade control structures using logs or boulders upstream and downstream of culverts to reduce velocities through culverts and create resting pools.	13	Adult migration through these culverts is limited by high flow velocities and a lack of pools at culvert inlets and outlets.

[a] Refer to the City of Duvall GIS system map of streams for locations of reaches.

Segment 4, and culverts underneath NE Third Avenue and NE Kennedy Drive. Re-arrangement of material at the collapsed wooden bridge and concrete flume in addition to grade control structures constructed as part of Priority 1 should be sufficient to provide adequate fish passage.

- Priority 5: Remove migration barriers in Segments 5 and 6 to allow both adult and juvenile salmon to access habitat in the upper segments. These migration barriers include culverts at the stormwater detention pond and along NE Miller Street.

Cherry Creek Tributary A

Table 3 lists potential restoration projects for Cherry Creek Tributary A. These restoration projects are prioritized based on removing migration barriers and improving conditions in sequential order, from the Duvall city limits to the headwaters of the stream (see Figure 5). The top two priority projects are described below.

- Priority 1: Remove migration barriers in Segments 1 and 2 to allow adult salmon access to spawning habitat within Duvall. These migration barriers include the culverts underneath NE Cherry Valley Road and NE Fourth Avenue, the braided channel immediately upstream of NE Cherry Valley Road, and the high-gradient channel in Segment 2. Suitable spawning habitat exists within Segment 2, but migration barriers are preventing adults from accessing this area.

- Priority 2: Remove migration barriers and improve habitat in Segment 3. These migration barriers include three culverts between NE Fourth Avenue and Rasmussen Lake, and a cascade created near 270th Place NE.

Cherry Creek Tributary B

Table 4 lists potential restoration projects for Cherry Creek Tributary B. These restoration projects are based on removing migration barriers and improving conditions in sequential order, from the Duvall city limits to the headwaters of the stream (see Figure 5). The top priority project is described below.

- Priority 1: Remove migration barriers in Segments 1 and 2 to allow adult salmon access to spawning habitat within Duvall. These migration barriers include the culverts underneath NE Cherry Valley Road and NE Rupard Road, and the braided channel immediately upstream of NE Cherry Valley Road.

Table 3. Potential restoration projects within Cherry Creek Tributary A in Duvall, Washington (see Figure 5).

Segment No.	Reach No. [a]	Potential Restoration Action	Priority	Rationale
1	5-6	Improve fish passage through the culvert underneath NE Cherry Valley Road by creating a plunge pool. This will require installing large woody debris and boulders as bed controls to create a plunge pool at the culvert outlet.	1	This culvert is a migration barrier to fish using upstream habitat.
1	8	Improve riparian vegetation that is limiting adult spawning and migration in this reach. This requires selectively removing invasive species and planting native tree, shrub, and herbaceous species along the stream banks.	2	The channel is clogged by reed canarygrass, which restricts migration through this reach.
2	31-41	Provide bed controls to improve adult migration in this segment. This requires installing log and boulder weirs in several high-gradient areas where partial migration barriers occur.	4	The stream cascades over existing bed controls but the gradient is too high and plunge pools are not present.
3	42	Replace the culvert underneath NE Fourth Avenue that is restricting adult migration. This requires excavation to remove the existing culvert and replacing it with a bottomless arch culvert. Install large woody debris and boulders as bed controls to create a plunge pool at the culvert outlet.	3	The slope of this culvert and the outfall drop is a migration barrier to adult salmon.
3	48	Provide bed controls to improve adult migration at the upstream end of the 270th Place NE culvert. This requires installing log and boulder weirs through a cascade where a migration barrier occurs.	5	The stream cascades over a clay layer and the gradient is too high.
3	51	Replace the culvert underneath a private driveway to 15926 NE Fourth Avenue that is restricting adult migration. This requires excavation to remove the existing culvert and replacing it with a bottomless arch culvert.	6	This culvert is undersized and may be a migration barrier to adult salmon.
3	55	Replace the culvert underneath a driveway to the old water tower that is restricting adult migration. This requires excavation to remove the existing culvert and replacing it with a bottomless arch culvert.	8	This culvert may be a migration barrier to adult salmon.
3	60	Replace the culvert underneath the berm containing Rasmussen Lake that is restricting adult migration. This requires excavation to remove the existing culvert and replacing it with a bottomless arch culvert. Install large woody debris and boulders as bed controls to create a plunge pool at the culvert outlet.	7	The slope of this culvert and the outfall drop is a migration barrier to adult salmon.

[a] Refer to the City of Duvall GIS system map of streams for locations of reaches.

Table 4. Potential restoration projects within Cherry Creek Tributary B in Duvall, Washington (see Figure 5).

Segment No.	Reach No. [a]	Potential Restoration Action	Priority	Rationale
1	6-8	Improve fish passage through the culvert underneath NE Cherry Valley Road by creating pools at both ends. This requires removing quarry spalls and creating a plunge pool at the culvert outlet, and removing quarry spalls at the culvert inlet. Install large woody debris and boulders as bed controls to create a plunge pool at the culvert outlet.	1	Adult salmon migration through this culvert is limited by the lack of deep pools at the inlet and outlet of the pipe.
2	9-10	Remove sediment deposits in the channel between NE Cherry Valley Road and NE Rupard Road that is limiting adult spawning and migration. This will require selectively excavating sediment deposits interspersed with the existing vegetation, and lining the stream channel with gravels. Enhance riparian vegetation in this reach by selectively removing invasive species and planting native tree, shrub, and herbaceous species along the stream banks.	3	The channel is clogged by sediment and reed canarygrass, which restricts migration through this reach.
2	11	Replace the culvert underneath NE Rupard Road that is restricting adult salmon migration. This requires excavation to remove the existing culvert and replacing it with a bottomless arch culvert.	2	Sediment from erosion in upstream reaches has clogged the culvert with sediment, which is causing a partial migration barrier.

[a] Reaches are identified in the City of Duvall GIS Stream Layer.

Preliminary Site Plans

Based on discussions with the City of Duvall, six of the potential restoration projects identified in Tables 1 and 2 were selected for further development. These include two restoration projects in Thayer Creek Segment 1, two restoration projects in Thayer Creek Segment 2, one restoration project in Coe-Clemons Creek Segment 3, and one restoration project in the Coe-Clemons Creek slump area in Segment 4. The following preliminary site plans for each of the six projects include a description of existing stream habitat, restoration goals and objectives, construction plans, and cost estimates.

The overall goal of this fish habitat restoration plan for the six restoration projects is to enhance or restore components of functioning fish habitat in the tributaries to the Snoqualmie River located within Duvall. These fish habitat components include instream large woody debris and small woody debris, meandering channels, stable banks with overhanging native vegetation, sources for future large woody debris and small woody debris recruitment, streambed materials for spawning and refuge, pools, riffles, aggregations of streambed materials, healthy hyporheic flows (shallow groundwater in floodplain gravels), and accessible fish passage.

Thayer Creek Segment 1

Two restoration projects are located within Segment 1 of Thayer Creek (see Table 1). These projects include restoration of the channel and riparian buffer in Segment 1 and replacement of the culvert. These projects lie within the Snoqualmie River floodplain and extend from the confluence with the Snoqualmie River to the Snoqualmie Valley Trail, located on the abandoned railroad berm (see Figure 3).

Description of Existing Stream Habitat

A summary of the King County Level I stream habitat inventory performed on Thayer Creek Segment 1 (Herrera 2002) is discussed below. The following description of existing stream habitat in Segment 1 includes the results of the habitat survey, a description of the riparian soils, channel substrate, bank stability, channel morphology, large woody debris, pool quality, and riparian vegetation.

Proceeding upstream from the confluence with the Snoqualmie River to the Snoqualmie Valley Trail, fish habitat characteristics in the lower 433 feet of Thayer Creek are consistent. Table 5 lists the habitat types, channel dimensions (average width, average depth, maximum depth of pools, total length of each habitat type), and pool quality index for Segment 1 of Thayer Creek. The first 370 feet of the stream consists of a series of runs, low-gradient riffles, plunge pools formed by a clay layer, and dammed pools formed by small woody debris jams. The channel is confined as it flows through an incised ravine, and there is a backwater effect from the river that floods some of the lower reaches. Approximately 370 feet upstream of the mouth, there is a 26-inch steel culvert that is partially clogged. This culvert lies underneath a dirt road (referred to

Table 5. Stream survey results for Thayer Creek Segment 1 in Duvall, Washington.

Reach No.	Habitat Type No. [a]	Habitat Type	Average Width (ft.)	Average Depth (ft.)	Maximum Depth (ft.)	Length (ft.)	Pool Quality Index	Comments
1	5	Run	5.0	2.8	–	82.0	–	Survey started at confluence with Snoqualmie River
2	1	Low-gradient riffle	2.0	1.3	–	29.5	–	Incised ravine in Snoqualmie River floodplain
3	5	Run	2.5	1.4	–	13.1	–	
4	8	Plunge pool	2.5	1.5	1.9	8.2	4	
5	1	Low-gradient riffle	1.8	1.3	–	8.9	–	
6	8	Plunge pool	3.6	1.4	1.7	10.5	4	
7	1	Low-gradient riffle	2.5	1.8	–	9.8	–	
8	13	Dammed pool	3.8	1.9	2.5	3.3	5	
9	5	Run	3.8	0.7	–	154.5	–	
10	14	Mid-channel pool	5.0	0.9	1.0	13.8	4	
11	5	Run	5.0	1.3	–	16.1	–	
12	13	Dammed pool	6.2	2.4	2.7	19.0	5	
13	7	Trench/chute	2.7	2.5	–	18.0	–	26-inch steel culvert under access road
14	5	Run	4.9	1.5	–	45.9	–	
					Total	432.6		

[a] Habitat types are defined in Herrera 2002.

as the lower access road) that provides access to farm fields on both sides of the stream. In Segment 1, the average wetted stream width ranges from 2.0 to 6.2 feet and the average wetted depth ranges from 0.7 to 2.8 feet.

Riparian Soils and Channel Substrate

The soil survey of King County identifies one soil type in the Thayer Creek Segment 1 survey area: Briscot silt loam (USDA 1973). Briscot silt loam is located on the floodplain between the Snoqualmie River and the abandoned railroad berm. The soils observed in the stream banks and streambed generally resemble this mapped soil type.

The dominant stream channel substrate in Thayer Creek Segment 1 is silt/organics and the secondary substrate is sand. Spawning gravels in this segment are judged poor, due to the lack of gravels and silt embeddedness.

Bank Stability and Channel Morphology

The stream banks in Thayer Creek Segment 1 are degrading because of artificial bed controls and a steep gradient near the confluence of the stream with the Snoqualmie River. Segment 1 is characterized by an artificially straightened channel that is downcutting and forming incised and unstable banks. It is assumed that this segment was straightened to maximize agricultural use of this area. The culvert located approximately 370 feet upstream of the mouth is acting as a bed control. The channel downstream of this culvert is downcutting to match the elevation of the Snoqualmie River. This downcutting has created steep banks (1**:**1) that are 10 to 15 feet high and unstable. Clay layers exposed in the stream bottom are acting as temporary bed controls and creating small waterfalls and plunge pools. The average gradient in Segment 1 is approximately 2 percent. The gradient at the lower portion of the segment, near the river, is approximately 5 percent. The average gradient of the upper portion of Segment 1 is approximately 1 percent.

Large Woody Debris and Pool Quality

There is no large woody debris in the wetted channel of Thayer Creek Segment 1. The lack of large woody debris in the channel appears to be caused by the clearing of riparian vegetation, which is preventing recruitment.

Pool quality indexes (PQI) were assigned for five pools observed in Thayer Creek Segment 1. The pool quality index rating system is used to evaluate the size of pools based on width and depth and the amount of cover available to fish. In general, pool quality is judged to be excellent when the pool is wider and deeper than the average stream channel and abundant cover is present. Pools that are narrow, shallow, and exposed are rated as poor quality. This rating system assigns a numerical value of 1 to 5, with 1 meaning poor quality and 5 meaning excellent quality.

Segment 1 contains two plunge pools, two dammed pools, and one mid-channel pool. Most of these pools have widths less than 10 percent of the average stream width, are shallow, and lack woody cover. The maximum depths of these pools ranged between 1.0 and 2.7 feet, and most of

the pools were rated with a PQI of 4. Overall, pools in the surveyed area provide fair rearing habitat because they lack large woody debris as cover.

Riparian Vegetation

Because of clearing by private property owners and adjacent land uses, the width of the riparian zone along Thayer Creek Segment 1 varies. Vegetation throughout the riparian zone consists of trees, shrubs, and herbaceous species in three canopy layers. The banks are relatively steep and the riparian zone is narrow. The southern bank is covered with Himalayan blackberry (*Rubus armeniacus*), salmonberry (*Rubus spectabilis*), and reed canarygrass (*Phalaris arundinacea*), while the northern bank has black cottonwood (*Populus balsamifera*), red alder (*Alnus rubra*), thimbleberry (*Rubus parviflorus*), and Japanese knotweed (*Polygonum cuspidatum*).

Fish Access

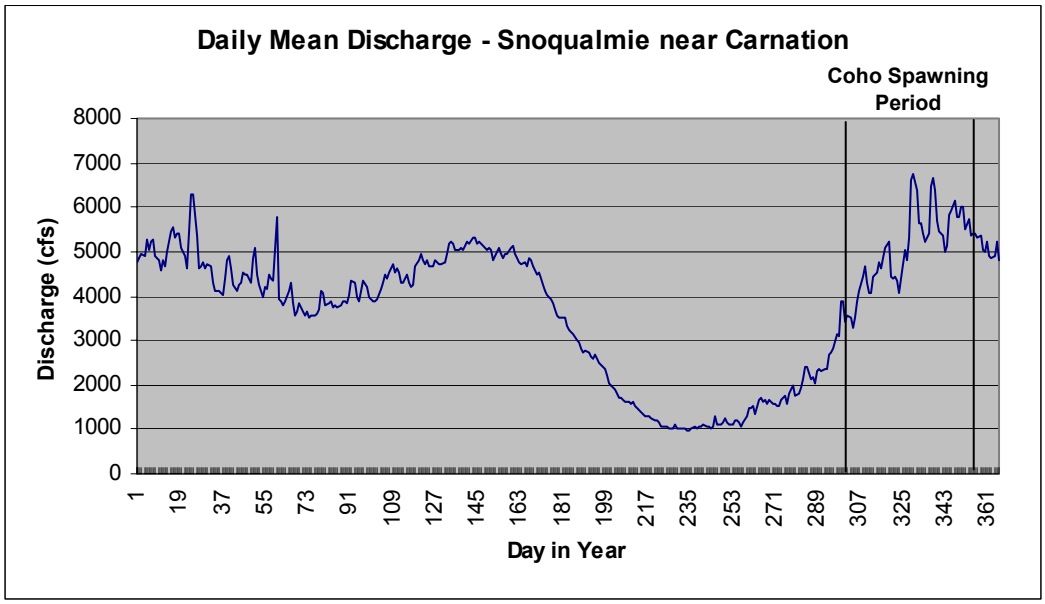
In an effort to estimate the ability of fish to migrate into Thayer Creek from the Snoqualmie River, the relationship between the timing of fish passage and spawning and seasonal variation in river stage was evaluated. Of the numerous species that exist seasonally or year-round in the Snoqualmie River, coho salmon and steelhead trout are the only likely spawning species for which upward passage into Thayer Creek may be important. Adult coho migration into Snoqualmie River tributaries occurs from early September to late October, with peak spawning occurring from mid-November to early December (Table 6). Thayer Creek may also provide seasonal spawning habitat to winter-run steelhead between March and June, though this is less likely (WDFW 1993).

Table 6. Coho life stages and timing.

Month	Jan.		Feb.		Mar.		Apr.		May		June		July		Aug.		Sept.		Oct.		Nov.		Dec.	
Entry																								
Spawn																								
Incubation																								
Rearing																								

Young coho can be found in natal streams year-round. The peak of migration for smolts in the Snoqualmie River watershed typically occurs in mid-May. Although no study has identified coho spawning times in the Snoqualmie River tributaries in the Duvall area, adult coho salmon were observed in Thayer Creek during November and December (Herrera 2002). Two USGS stream gauges are located on the Snoqualmie River: one at Duvall (Station 12150400) and one near Carnation (Station 12149000). The Duvall station reports the current river stage only; historical data from which to evaluate seasonal variation are not available at this time from this stream gauge. This corresponds to an increase in river stage in the Snoqualmie River, as illustrated in Table 7. It appears that fish passage is ensured only when the stage of the Snoqualmie River at the mouth of Thayer Creek is at or above 4,000 cfs. This flow corresponds to a river elevation of 28.0 feet.

Table 7. Seasonal variation in stage of Snoqualmie River, based on 72 years of record.



While passage appears to be possible during years of normal flow, it is a near certainty that it is impeded during years of low flow. In these low-flow years, the steep gradient, incised channel and lack of resting pools make access to Thayer Creek difficult for fish. As such, passage into Thayer Creek could be substantially improved during low-flow years, and possibly during normal-flow years, by creating a series of steps from the mouth of the stream up to an elevation of approximately 30.0 feet.

Additional assessment of river stage information correlated with fish migration will be required during the design phase of this restoration project.

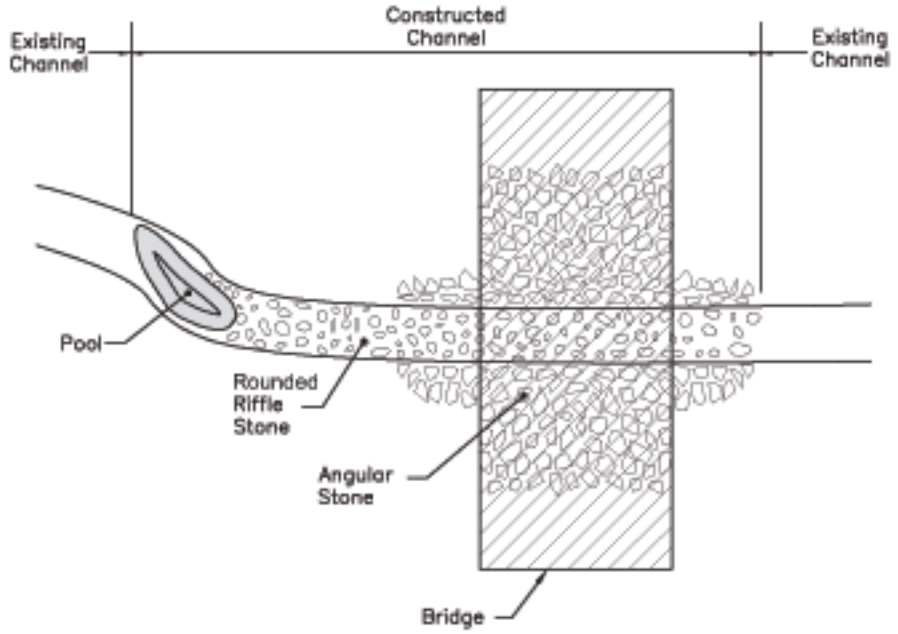
Restoration Goals and Objectives

The overall objective of the Thayer Creek Segment 1 restoration project is to enhance and restore fish habitat functions in order to create a sustainable system of passage, spawning, rearing, and refuge.

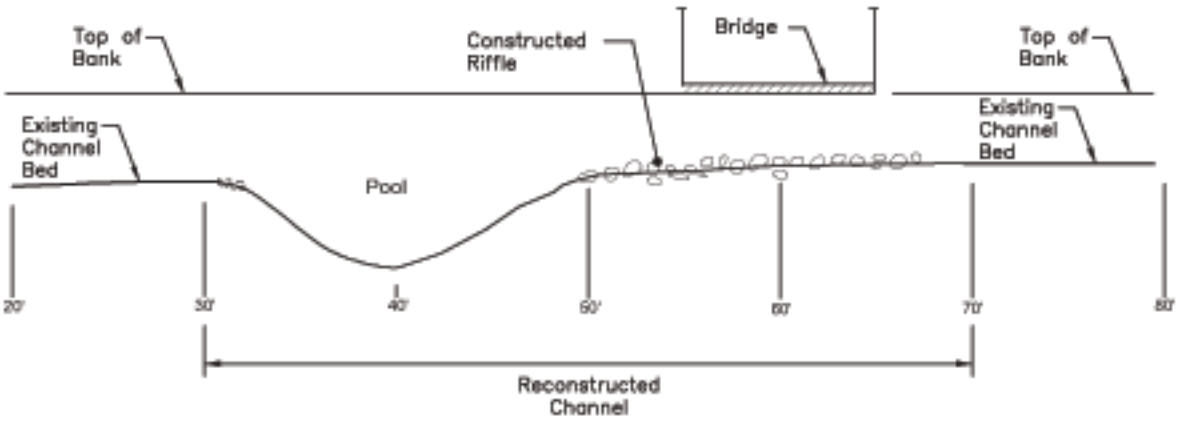
Restoration Goal 1: Improve fish passage.

Objective 1: Remove fish passage barriers at the culvert.

Action: The City of Duvall proposes replacing the existing culvert in Segment 1 of Thayer Creek with a truck-bed bridge (Figure 6). The proposed truck-bed bridge would consist of a 40-foot long modified truck bed supported on 2-foot by 2-foot by 6-foot solid precast concrete blocks (i.e., ecology blocks). In general, bridges offer an advantage over culverts in that they allow natural channel features that promote fish passage. Furthermore, bridges typically provide greater



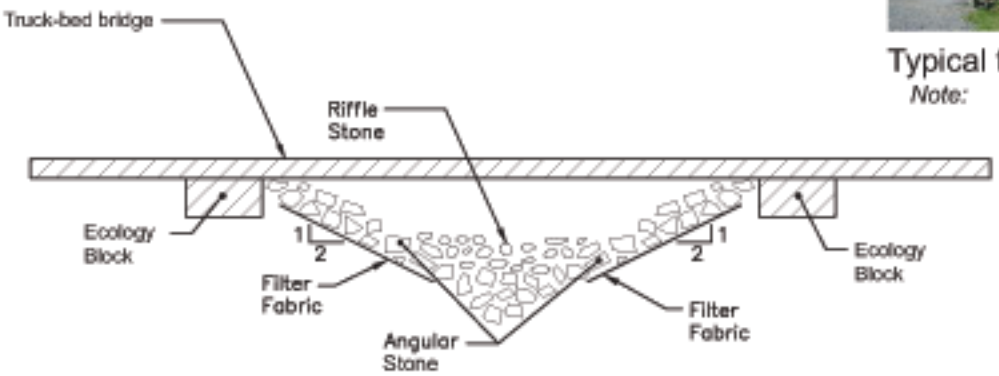
Typical Proposed Plan View for Bridge Crossings



Typical Proposed Profile for Crossings

Typical truck-bed bridge

Note: Access road bridge will not have railings.



Typical Proposed Cross-Section Under Bridge at Crossings

Source: Interfluve 2002

Figure 6. Typical truck-bed bridge and details.

capacity than culverts and are therefore less likely to create velocity barriers or to become blocked. Culverts often provide grade control on streams by creating a fixed, non-deformable bed elevation at the entry and exit of the culvert. Bridges avoid these artificial grade control conditions.

Objective 2: Remove the headcut in the stream near the confluence with the Snoqualmie River.

Action: Construct a new stream channel with higher sinuosity, a longer channel, and a gentler gradient to decrease erosive flows. Incorporate grade control structures near the mouth of Thayer Creek to prevent erosion of the channel during low flow events. Incorporate large woody debris structures and streambed gravel to roughen the channel, which will decelerate high flow rates.

Performance Standard: Document a 50 percent increase in fish presence in the upper reaches of Thayer Creek and increased use of Segment 1.

Restoration Goal 2: Develop a sustainable ecosystem for fish habitat.

Objective 1: Stabilize bank erosion.

Action: Regrade stream banks to a sustainable slope of 4**:**1. Establish a high-flow and low-flow channel within the stream to prevent erosive forces from scouring the banks. Increase the density of stream bank plantings to prevent erosion of the banks.

Objective 2: Decrease invasive weed colonization.

Action: Clear and grub all invasive weed material and dispose of off-site while protecting high-quality native vegetation on site. Invasive weeds of particular concern include reed canarygrass, Japanese knotweed, Himalayan blackberry, and evergreen blackberry (*Rubus laciniatus*). Replant buffer with native forested and scrub/shrub species to compete with invasive weeds that are present on the site.

Objective 3: Enhance large woody debris and small woody debris recruitment and improve the health of the hyporheic zone.

Action: Enhance a 100-foot-wide forested and scrub/shrub stream buffer for Thayer Creek (Duvall 1991). Forested plantings will provide sustainable hardwood for large woody debris recruitment over the long term. Construction of gently sloping banks will allow the large woody debris to fall into the stream, rather than across the stream. In the interim, shorter-lived deciduous trees and shrubs will provide small woody debris recruitment in the stream. Increased buffer width and health will facilitate cool, clean, oxygenated and nutrient-rich inputs into the hyporheic zone.

Performance Standard: Document an 85 percent reduction of the presence of invasive weeds on the project site and a 90 percent coverage of the riparian buffer with native species after 5 years.

Restoration Goal 3: Enhance fish habitat for rearing, refuge, and spawning.

Objective 1: Provide large woody debris structures in the stream for rearing habitat.

Action: Install a minimum of two large logjam structures in the stream. Install one structure at the diversion of the new channel from the existing channel. Install a second structure near the confluence of Thayer Creek with the Snoqualmie River. Install a minimum of six smaller large woody debris structures along the stream between these two large structures. Large woody debris provides refuge habitat for fry and juvenile fish. In addition, it provides hydrologic diversity that interacts with the streambed material and the hyporheic zone to encourage spawning.

Objective 2: Improve the substrate for refuge and spawning.

Action: Install streambed gravels, riffles, and pool material in areas adjacent to, and downstream from, large woody debris structures. These materials encourage spawning, and provide pore spaces for fry to feed from the nutrient-rich hyporheic zone and as refuge for juveniles from predation.

Performance Standard 1: Document a 50 percent increase in the presence of gravel material and appropriate pore spaces for juvenile refuge in the stream.

Performance Standard 2: Document a 50 percent increase in spawning activity and presence of juveniles and fry in Thayer Creek.

Performance Standard 3: Document an increase in hyporheic flows immediately downstream from the large woody debris structures.

Construction

This restoration project to enhance Segment 1 of Thayer Creek involves creating 440 linear feet of stream channel, removing two fish passage barriers, and enhancing 2 acres of riparian buffer (see Figure 7).

The project will be constructed in three phases to allow for variable funding sources. Each phase will be designed independently of adjacent phases to allow for flexibility in the order of phase implementation. Phase 1 will consist of the lower portion of Segment 1, from the confluence to the dammed pool located 165 feet from the confluence. Phase 2 will consist of the upper portion

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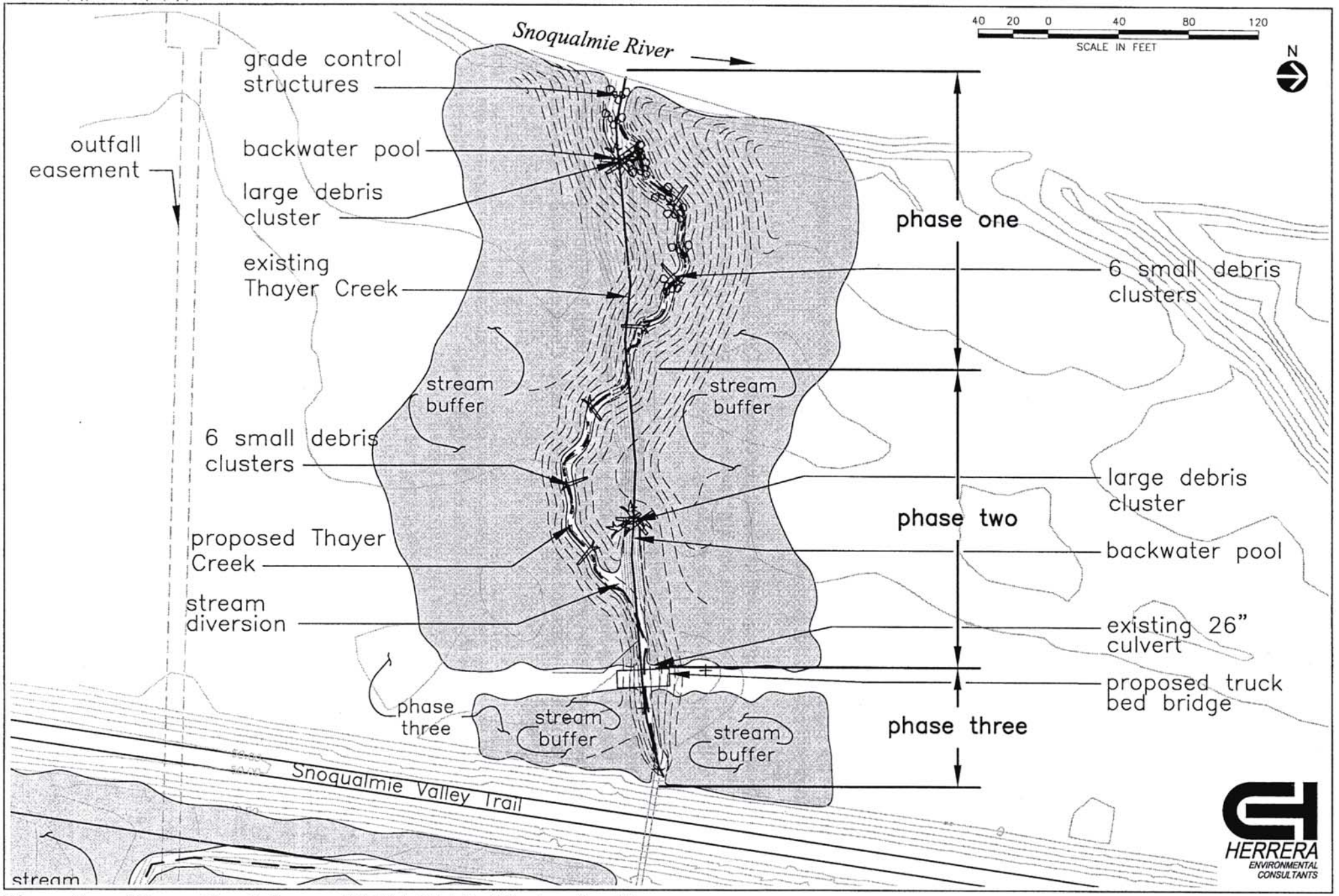


Figure 7. Thayer Creek Segment 1 Fish Habitat Restoration Plan.

of Segment 1 from the dammed pool to the 26-foot culvert. Phase 3 will include the 26-foot culvert and the section of stream between the culvert and the Snoqualmie Valley Trail. The culvert under the Snoqualmie Valley Trail is not included in this project.

Phase 1 Construction

Fish habitat restoration for Phase 1 will create 220 linear feet of stream channel and enhance 1.10 acres of riparian buffer. The primary functions of this phase of the project are to improve fish passage, provide refuge and prevent further erosion of the stream channel. The overall gradient of this stream segment will be approximately 0.5 percent. Because salmon do not access the stream at Snoqualmie River flows below an elevation of 28 feet, structures below 28 feet will be designed for grade control and to resist high flows. Approximately eight structures, consisting of a wedge of angular stones, will be placed an average of 15 feet apart. Grade control structures will be placed beginning at the mouth of Thayer Creek adjacent to the Snoqualmie River. It will be necessary to place geotextile material under each structure to prevent the angular stones from sinking into the soft sediments of the stream channel. Each structure will raise the streambed a maximum of 8 inches.

A large engineered logjam will be placed just upstream of the stream diversion. Several smaller wood clusters will be placed in the upper reaches of this project, above elevation 28 feet. This logjam will prevent the stream from eroding into the abandoned channel.

Riparian buffer plantings will consist of native shrub species placed on an average of 5 feet on center and tree species placed on an average of 20 feet on center. Invasive species will be removed from existing areas of high-quality native vegetation. Where possible, high-quality areas of native vegetation will be protected in place. The large invasion of Japanese knotweed on the bank of the Snoqualmie River north of the Thayer Creek channel will be removed within the restored buffer.

Phase 1 will reconnect with the existing stream channel approximately 160 feet from the Snoqualmie River. If Phase 1 is constructed prior to Phase 2, temporary drop structures may need to be constructed where the proposed stream channel connects to the existing stream channel to provide fish passage between the two channel sections.

Phase 2 Construction

The fish habitat restoration for Phase 2 will consist of the creation of 220 linear feet of stream channel and the restoration of 1.10 acres of riparian buffer. The primary functions of this phase of the project are to improve fish passage, and provide refuge and spawning habitat. The overall gradient of this stream segment will be approximately 1.5 percent.

A large engineered logjam will be placed on the downstream side of the stream diversion to prevent the stream from reestablishing in the existing channel. Several smaller wood clusters will be placed in the upper reaches of this project, above elevation 28 feet.

Riparian buffer plantings will consist of native shrub species placed on an average of 5 feet on center and tree species placed on an average of 20 feet on center. Invasive species will be removed from existing areas of high-quality native vegetation. Where possible, high-quality areas of native vegetation will be protected in place.

Phase 1 will connect with the existing stream channel downstream of the 26-inch culvert and approximately 160 upstream of the Snoqualmie River. If Phase 2 is constructed prior to Phase 1, temporary drop structures may need to be constructed where the proposed stream channel connects to the existing stream channel to provide fish passage between the two channel sections. If Phase 2 is constructed prior to Phase 3, a temporary adjustment of the grade adjacent to the culvert may be necessary to provide fish passage between the two channel sections.

Phase 3 Construction

The primary functions of this phase of the project are to remove the fish barrier at the existing culvert, improve fish passage, and enhance riparian buffer habitat. The fish habitat restoration for Phase 3 will consist of the replacement of a 26-inch culvert and the restoration of approximately 60 linear feet of stream channel.

Culvert Replacement

The Washington Department of Fish and Wildlife (WDFW) has established regulations for fish passage requirements at water crossing structures in the Washington Administrative Code (WAC 220-110-010). One of the principles WDFW established for water crossings states, "Cumulative impacts and risks of water crossings can be avoided or minimized by consolidating water crossings, *employing full-span bridges,* by simulating a natural channel through culverts, or removing water crossings. Access solutions that do not require water crossings are preferred."

The City of Duvall proposes replacing the existing culvert in Segment 1 of Thayer Creek with a truck-bed bridge (Figure 7). Bridges offer an advantage over culverts in that they allow natural channel features that promote fish passage. Furthermore, bridges typically provide greater capacity than culverts and are therefore less likely to create velocity barriers or to become blocked. Culverts often provide grade control on streams by creating a fixed, non-deformable bed elevation at the inlet and outlet of the culvert.

The culvert will be replaced with a truck-bed bridge. The creek channel in the location of the current culvert will have to be restored when the existing culvert is removed. Based on the channel profile and observed channel character, the culvert will be replaced with a constructed riffle and pool sequence that ties in with existing riffle and pool features in the stream channel adjacent to the existing culvert. The riffle will be constructed using immobile rounded river gravel at an approximate grade of 1.5 percent. The reconstructed channel bed will be raised relative to the elevation of the current culvert inverts, and will include a short riffle and pool. Channel cross-section configuration through the reconstructed channel segment (where the culvert is replaced) will approximate the existing channel dimensions immediately upstream and downstream of the culvert, and will tie in to existing channel banks smoothly.

This crossing will incorporate two to three riffle-pool sequences to even the stream grade through the truck-bed bridge. Riparian buffer plantings will consist of native shrub species placed on an average of 5 feet on center and tree species placed on an average of 20 feet on center. Invasive species will be removed from existing areas of high-quality native vegetation. Where possible, high-quality areas of native vegetation will be protected in place.

If Phase 3 is constructed prior to Phase 2, temporary drop structures may need to be constructed downstream of the culvert to provide fish passage between the two channel sections.

Cost Estimate

The estimated cost of the fish habitat restoration project for Thayer Creek Segment 1 is projected to be approximately $738,800 (see Table 8). The City of Duvall can decrease the expected cost of the wood structures by stockpiling wood material for woody debris structures prior to the commencement of the public bid process. A detailed cost estimate is provided in Appendix C.

Table 8. Thayer Creek Segment 1 fish habitat restoration plan conceptual cost estimate.

Item	Phase 1	Phase 2	Phase 3	Overall Project
Design (20% of construction costs)	$ 45,000.00	$ 35,000.00	$ 10,000.00	$ 90,000.00
Permitting (10% of construction costs)	$ 20,000.00	$ 19,000.00	$ 6,000.00	$ 45,000.00
Site Preparation	$ 34,912.60	$ 34,463.00	$ 6,700.00	$ 76,075.60
Earthwork	$ 41,250.00	$ 16,890.00	$ 2,780.00	$ 60,920.00
Streambed Gravels	$ 9,957.50	$ 3,090.00	$ 725.00	$ 13,772.50
Truck-bed Bridge/Culverts	–	–	$ 11,350.00	$ 11,350.00
Wood Structures	$ 25,300.00	$ 18,800.00	$ 250.00	$ 44,350.00
Soils and Permanent Erosion Control	$ 29,831.92	$ 25,356.36	$ 3,183.28	$ 58,371.56
Plantings	$ 26,808.32	$ 26,808.32	$ 22,819.56	$ 76,436.20
Temporary Irrigation	$ 33,000.00	$ 33,000.00	$ 9,000.00	$ 75,000.00
Maintenance – 2 years	$ 17,280.00	$ 17,280.00	$ 5,760.00	$ 40,320.00
Subtotal	$283,340.34	$229,687.68	$ 78,547.84	$591,575.86
8.6% tax	$ 24,367.27	$ 19,753.14	$ 6,755.11	$ 50,875.52
Subtotal	$307,707.61	$249,440.82	$ 85,302.95	$642,451.38
15% contingency	$ 46,156.14	$ 37,416.12	$ 12,795.44	$ 96,367.71
Total	**$353,863.75**	**$286,856.94**	**$ 98,098.40**	**$738,819.09**

This estimate assumes that the project will endeavor to balance cut and fill on the site by backfilling segments of the abandoned channel with fill material removed from the proposed channel. Because of the lengthening of the stream profile and easing of the stream cross-section, there will be excess fill material that must be disposed of offsite regardless of efforts to reduce

material by backfilling the old channel. The City of Duvall can decrease the expected cost of the material disposal by providing a nearby location, outside of the 100-year floodplain (FEMA 1995), to dispose of the excess material.

Additional costs could be saved by organizing teams of volunteers to install plants.

Thayer Creek Segment 2

Two restoration projects are located within Segment 2 of Thayer Creek (see Table 1). These projects include improving the riparian zone and replacing the culvert under the access road. These projects extend from the Snoqualmie Valley Trail to the western boundary of the Duvall Tech Center adjacent to SR 203. Restoration in Segment 2 does not address the culvert under the Snoqualmie Valley Trail.

Description of Existing Stream Habitat

A summary of the King County Level I stream habitat inventory performed on Thayer Creek Segment 2 (Herrera 2002) is discussed below. The following description of existing stream habitat in Segment 2 includes the results of the habitat survey, a description of riparian soils, channel substrate, bank stability, channel morphology, large woody debris, pool quality, and riparian vegetation.

Fish habitat within Segment 2 between the Snoqualmie Valley Trail and an access road culvert (reaches 15-26) primarily provides migration and rearing habitat (see Table 9). Proceeding upstream of the culvert under the abandoned railroad berm where the Snoqualmie Valley Trail crosses Thayer Creek, the channel turns south and parallels the eastern bank of the Snoqualmie Valley Trail for approximately 275 feet before turning east for another 156 feet to an access road culvert. The channel paralleling the Snoqualmie Valley Trail provides habitat such as runs, plunge pools formed by log weirs, and damned pools formed by small woody debris jams. The channel between the Snoqualmie Valley Trail and access road culvert has a higher gradient and is downcutting to a clay layer, which forms low-gradient riffles and runs. The access road culvert (a 26-inch steel pipe) is partially clogged and constricts the channel. The average wetted width in Segment 2 ranges from 1.5 to 4.8 feet, the averaged wetted depth ranges from 0.7 to 2.5 feet, and the maximum pool depth ranges from 1.0 to 1.5 feet.

Riparian Soils and Channel Substrate

The soil survey of King County identifies two soil types in the Thayer Creek Segment 2 project area: Nooksack silt loam and Puget Sound silty clay loam (USDA 1973). Nooksack silt loam is well-drained soil formed in alluvium in river valleys. Puget silty clay loam is a poorly drained soil formed in alluvium in river valleys and is considered to be hydric (USDA 1988). The soils observed in the stream banks of Segment 2 generally resemble Nooksack silt loam.

Table 9. Stream survey results for Thayer Creek in Duvall, Washington.

Segment and Reach No.	Habitat Type No. [a]	Habitat Type	Average Width (ft.)	Average Depth (ft.)	Maximum Depth (ft.)	Length (ft.)	Pool Quality Index	Comments
15	7	Trench/chute	2.7	2.5	–	78.7	–	36-inch circular concrete culvert under railroad berm
16	5	Run	4.2	1.0	–	151.9	–	
17	13	Dammed pool	3.7	1.2	1.4	14.1	4	
18	5	Run	4.5	0.9	–	44.9	–	
19	8	Plunge pool	4.1	0.9	1.0	12.1	4	
20	5	Run	4.8	1.1	–	49.5	–	
21	8	Plunge pool	7.0	1.1	1.5	4.9	4	Plunge pool formed by exposed pipe
22	1	Low-gradient riffle	3.1	0.6	–	22.3	–	Clay layer forming waterfall
23	5	Run	2.5	1.0	–	16.7	–	
24	1	Low-gradient riffle	1.5	0.7	–	17.4	–	Clay layer forming stream bottom
25	5	Run	2.5	0.9	–	76.4	–	
26	7	Trench/chute	2.7	1.0	–	21.3	–	26-inch steel culvert under access road
					Total	510.2		

[a] Habitat types are defined in Appendix A. Pool quality indexes are defined in Appendix B.

The dominant stream channel substrate in Thayer Creek Segments 2 is silt/organics and the secondary substrate is sand. Spawning gravels in this segment are judged poor, due to the lack of gravels and silt embeddedness. However, Segment 2 of the stream exhibits a higher amount of gravel than Segment 1.

Bank Stability and Channel Morphology

In Thayer Creek Segment 2, the stream banks are generally stable due to the low gradient of the segment and native vegetation established on the south side of the channel. It is assumed that this segment was realigned adjacent to the Snoqualmie Valley Trail to maximize agricultural use of this area. Artificial bed controls at relatively similar elevations reinforce stability in this segment. These artificial bed controls are provided by the culvert under the Snoqualmie Valley Trail and the culvert under the access road. However, a clay layer located 130 feet downstream of the access road culvert is providing a hardened point in the stream channel. Erosion of the channel is retarded at this point and is resulting in a plunge pool downstream that affects fish migration.

Large Woody Debris and Pool Quality

There is no large woody debris in the wetted channel of Thayer Creek Segment 2. The lack of large woody debris in the channel is likely due to clearing and removal of riparian vegetation that prevents recruitment. However, small woody debris (SWD) provides dammed pools and plunge pools in the stream adjacent to the Snoqualmie Valley Trail.

Pool quality indexes (PQI) were assigned for three pools observed in Thayer Creek Segment 2. Segment 2 pools consist of one plunge pool formed by an exposed pipe, an additional plunge pool, and one dammed pool. Most of these pools have widths less than 10 percent of the average stream width, are shallow, and lack woody cover. The maximum depths of these pools ranged between 1.0 and 2.7 feet, and most of the pools were rated with a PQI of 4. Overall, pools in the surveyed area provide fair rearing habitat because of their lack of large woody debris as cover.

Riparian Vegetation

The width of the riparian zone along Thayer Creek Segment 2 varies because of clearing by private property owners and adjacent land uses. Vegetation throughout the riparian zone consists of trees, shrubs, and herbaceous species in three canopy layers. The stream banks are relatively steep and the riparian zone is narrow. The south stream bank is covered with Himalayan blackberry, salmonberry, and reed canarygrass; the northern bank has black cottonwood, red alder, thimbleberry, and Japanese knotweed.

Restoration Goals and Objectives

The overall objective of the Thayer Creek restoration project in Segment 2 is to enhance and restore fish habitat functions in order to create a sustainable system of passage, spawning, rearing, and refuge (Figure 8).

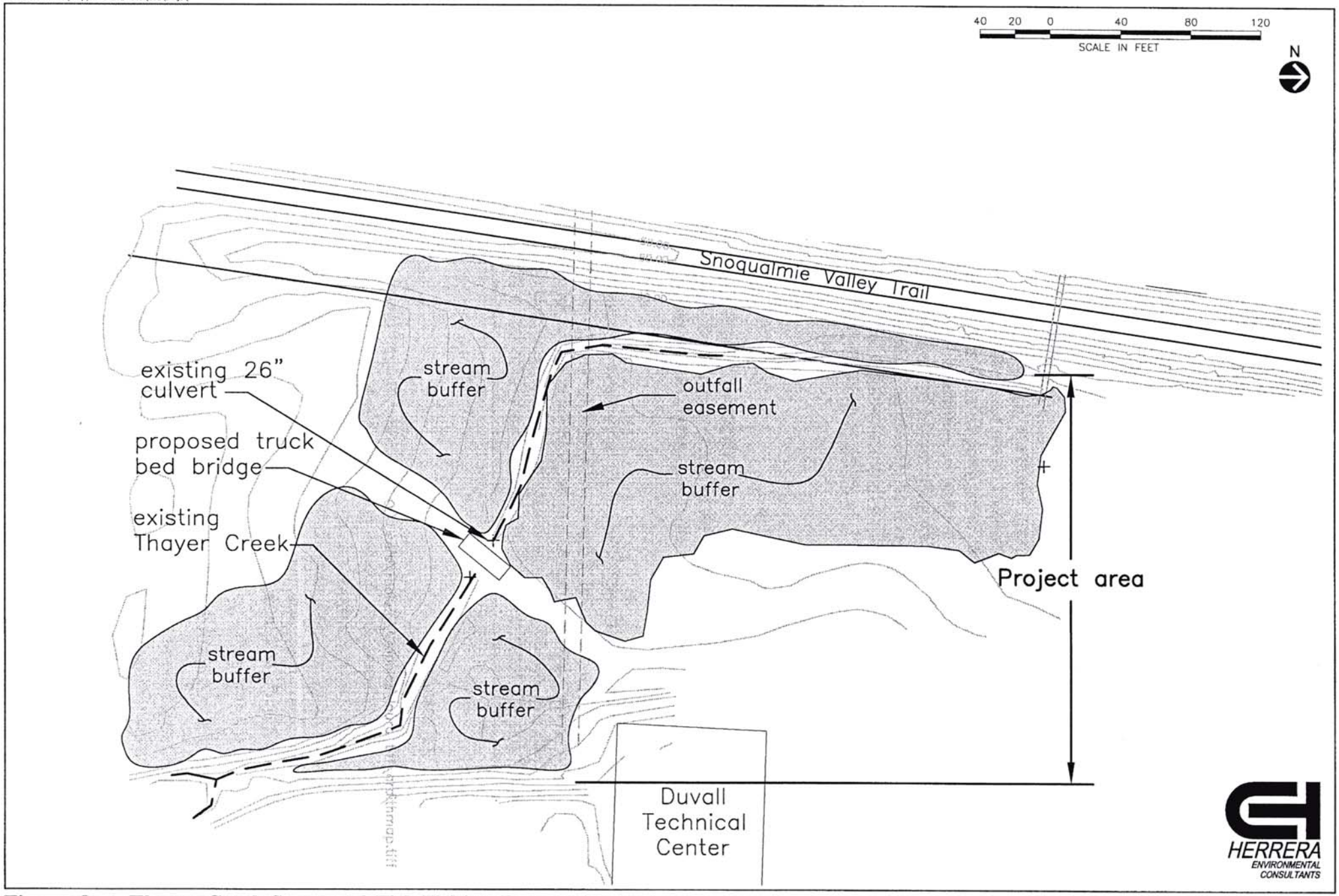


Figure 8. Thayer Creek Segment 2 Fish Habitat Restoration Plan

Restoration Goal 1: Improve fish passage.

Objective 1: Remove fish passage barrier at the culvert under the access road.

Action: The City of Duvall proposes replacing the existing culvert on Segment 2 of Thayer Creek with a truck-bed bridge (Figure 6) similar to the bridge placed at the existing 26-inch culvert in Segment 1.

Performance Standard: Document a 50 percent increase in fish presence in the upper reaches of Thayer Creek and increased use of Segment 2.

Restoration Goal 2: Develop a sustainable ecosystem for fish habitat.

Objective 1: Enhance large woody debris and small woody debris recruitment and improve the health of the hyporheic zone (the area in which nutrient-rich groundwater flows interact with oxygen-rich surface flows).

Action: Enhance a 100-foot forested and scrub/shrub stream buffer for Thayer Creek. Forested plantings will provide sustainable hardwood, large woody debris recruitment over the long term. In the interim, shorter-lived deciduous trees and shrubs will provide small woody debris recruitment in the stream. Increased buffer width and health will facilitate cool, clean, oxygenated, and nutrient-rich inputs into the hyporheic zone.

Objective 2: Decrease invasive weed colonization.

Action: Clear and grub all invasive weed material and dispose of offsite while protecting high-quality native vegetation on site. Remove roots to a depth of 18 inches while leaving topsoil on the site. Replant buffer with native forested and scrub/shrub species to compete with invasive weeds that are present on the site. Invasive weeds of particular concern include reed canarygrass, Japanese knotweed, Himalayan blackberry, and evergreen blackberry.

Performance Standard: Document an 85 percent reduction of invasive weeds on the project site and a 90 percent coverage of the riparian buffer with native species after 5 years.

Construction

This restoration project to enhance Segment 2 of Thayer Creek will remove one fish passage barrier and enhance 1.25 acres of riparian buffer. The project involves enhancing 300 linear feet of the stream channel from the east side of the Snoqualmie Valley Trail through the 26-inch culvert. The primary functions of this phase of the project are to remove the fish barrier at the existing culvert, improve fish passage, and enhance the riparian buffer habitat.

Recommendations for the bridge crossing, grade control, and riffle-pool concepts at the Segment 2 truck-bed bridge are identical to those for the Phase 3 truck-bed bridge in Thayer Creek Segment 1. The existing culvert in this location is slightly shorter. As a result, a shorter length of treatment is required. Currently, the channel bends north immediately above the culvert entrance. This bend will be moved downstream in the reconstructed channel to coincide with the pool location, thereby maintaining a relatively straight alignment through the riffle and under the bridge.

Riparian buffer plantings will consist of native shrub species placed an average of 5 feet on center and tree species placed an average of 20 feet on center. Large areas of native species located west of the existing culvert will be retained. Invasive species will be removed and, where possible, high-quality areas of native vegetation will be protected in place.

Cost Estimate

The estimated cost of the fish habitat restoration project for Thayer Creek Segment 2 is projected to be approximately $171,000 (see Table 10). A detailed cost estimate is included in Appendix C. The City of Duvall can decrease the expected cost of the project by organizing teams of volunteers to install plants.

Table 10. Thayer Creek Segment 2 fish habitat restoration plan conceptual cost estimate.

Item	Cost
Design (20% of construction costs)	$ 20,000.00
Permitting (10% of construction costs)	$ 10,000.00
Site Preparation	$ 14,500.00
Earthwork	$ 2,780.00
Streambed Gravels	$ 725.00
Truck-bed Bridge Culverts	$ 11,580.00
Soils and Permanent Erosion Control	$ 20,321.76
Plantings	$ 17,232.00
Temporary Irrigation	$ 22,500.00
Maintenance – 2 years	$ 17,280.00
Subtotal	$136,918.76
8.6% tax	$ 11,775.01
Subtotal	$148,693.78
15% contingency	$ 22,304.07
Total	**$170,997.84**

Coe-Clemons Creek Segment 3

This restoration project on Coe-Clemons Creek is located in Segment 3 within the wetland mitigation site created for the Copper Hill Square development (see Figure 4b). The goal of this restoration project is to improve migration and fish passage to upstream reaches.

Description of Existing Stream Habitat

A summary of the King County Level I stream habitat inventory performed on Segment 3 of Coe-Clemons Creek (Herrera 2002) is presented below. The following description of existing stream habitat in Segment 3 includes the results of the habitat survey, a description of the SR 203 culvert, a description of the riparian soils, channel substrate, bank stability, channel morphology, large woody debris, pool quality, and riparian vegetation.

The project area for this restoration site encompasses approximately 135 feet of stream channel through a recently created wetland mitigation site for the Copper Hill Square development, extending from an open water area near the Snoqualmie Valley Trail to a willow thicket on the downstream side of SR 203. The project area also includes the culvert under SR 203. Table 11 lists the habitat types, channel dimensions (average width, average depth, maximum depth of pools, total length of each habitat type), and pool quality index for the Coe-Clemons Creek Segment 3 project area.

Excessive bedload movement from sediment sources upstream of this segment has resulted in significant sediment aggradation in the SR 203 culvert and has caused the stream to breach its banks and flow through the wetland mitigation site downstream of the culvert. Silt fences and hay bales installed during construction of the Copper Hill Square development wetland mitigation project have disrupted the natural flow of water and sediment across the site. The lower 135 feet of Segment 3 between the Snoqualmie Valley Trail and the willow thicket consists of low-gradient riffle and run habitat that braids through reed canarygrass in multiple channels. The average wetted width ranges from 2.0 to 10.0 feet and the average wetted depth ranges from 0.3 to 1.6 feet.

SR 203 Culvert

The upgradient portion of Segment 3 in Coe-Clemons Creek includes an existing 6-foot-wide concrete culvert. The culvert conveys the mainstem of Coe-Clemons Creek under SR 203. The culvert is significantly aggraded with streambed sediments. The substrate is within 6 inches from the top of the culvert (see photos 5 and 6 in Appendix D).

Construction details of the culvert are unknown. As such, the depth of the culvert and amount of sedimentation is uncertain. Anecdotal information suggests that the culvert replaced a bridge as part of a highway-widening project of SR 203 by WSDOT approximately 40 years ago. It is uncertain if the old bridge was removed or abandoned and covered with embankment (earth berm). Construction of SR 203 included a significant quantity of embankment through the Coe-Clemons Creek ravine along the SR 203 right-of-way. The finished grade of SR 203 is approximately 15 feet above the culvert elevation. Given the typical construction practices at the approximate time of construction, the culvert is likely a 4-foot-deep box culvert sloping at approximately 2 percent. A 2 percent slope is consistent with recent field observations of the inlet and outlet of the culvert.

Table 11. Stream survey results for Coe-Clemons Creek Segment 3 in Duvall, Washington.

Segment and Reach No.	Habitat Type No. [a]	Habitat Type	Average Width (ft.)	Average Depth (ft.)	Maximum Depth (ft.)	Length (ft.)	Pool Quality Index	Comments
14	1	Low-gradient riffle	10.0	0.3	–	78.0	–	Braided channel confined by silt fence through Copper Hill Square mitigation site.
15	1	Low-gradient riffle	7.0	0.3	–	17.0	–	
16	5	Run	2.0	1.6	–	20.0	–	Historic channel with incised banks within Copper Hill Square mitigation site.
17	1	Low-gradient riffle	2.0	0.7	–	20.0	–	Incised channel with installed large woody debris.
					Total	135.0		

[a] Habitat types are defined in Appendix A.

Riparian Soils and Channel Substrate

The King County soil survey identifies two soil types in the Coe-Clemons Creek Segment 3 project area between the Snoqualmie Valley Trail and SR 203: Nooksack silt loam and Puget silty clay loam (USDA 1973).

The dominant stream channel substrate in Coe-Clemons Creek Segment 3 is silt/organics and the secondary substrate is sand. Spawning gravels in this segment of the stream are judged to be poor, due to the lack of gravels and silt embeddedness.

Bank Stability and Channel Morphology

Channel morphology in Segment 3 of Coe-Clemons Creek varies from a meandering channel confined by low banks to entrenched, artificially straightened channels. The stream banks are degraded due to excessive bedload movement from upstream sources and sediment deposition resulting in a braided channel (see photos 7 and 8 in Appendix D).

The substrate in the upper reach of Segment 3 and inside the culvert under SR 203 consists of a combination of fine sediment and large cobbles. The substrate in the culvert is within six inches from the top of the culvert. The upper reach of Segment 3 in the willow thicket has experienced recent and significant sedimentation. Sandbags recently placed along the creek to confine the channel have been overtopped with sediment and a new channel has cut through a recent riparian planting area (Figure 4b and photo 7 in Appendix D). This indicates a significant sediment source that may soon plug the culvert and impound the creek east of SR 203, creating a risk to both the highway and fish habitat. The risk is further compounded since it appears that the sediment load in Segment 3 and within the culvert has significantly increased within the past few years.

Channel morphology and sedimentation in Segment 3 is affected by the reach upstream of Segment 3 east of SR 203 (Segment 4). The streambed gradient changes from a steep-gradient ravine of nearly 10 percent in Segment 4 upstream of the SR 203 culvert to a low-gradient (1 to 2 percent) floodplain in Segment 3 downstream of the culvert. This creates a sediment accumulation area caused by a decrease in the sediment transport capacity in Segment 3. As described later in this report, several landslides in Segment 4 have contributed a significant load of sediment to Coe-Clemons Creek further exacerbating the natural sedimentation issues at the culvert.

Large Woody Debris and Pool Quality

The only large woody debris in the wetted channel of Coe-Clemons Creek Segment 3 is anchored rootwads installed in the wetland mitigation site. The lack of large woody debris in Segment 3 is likely due to the clearing of riparian vegetation, which prevents recruitment. No pools are present in the stream in the Copper Hill Square Mitigation Site due to the braided channel and sediment deposition. Two side channels formed within the Copper Hill Square Mitigation Site during high water events. Additional interventions have reduced the flow in these channels.

Riparian Vegetation

Because of clearing for residential and other adjacent land uses, the riparian zone of Coe-Clemons Creek in the Copper Hill Square Mitigation Site consists of an emergent wetland. Vegetation throughout the riparian zone consists of an open field of reed canarygrass, soft rush (*Juncus effusus*), and cattails (*Typha latifolia*). The mitigation site has been planted with riparian buffer species. These plants are young but can be expected to develop into a healthy riparian buffer. Due to its aggressive growth habit, reed canarygrass will continue to be a maintenance issue in this area. The area immediately downstream of the SR 203 culvert consists of a willow thicket dominated by Sitka willow (*Salix sitchensis*), Pacific willow (*Salix lasiandra*), and salmonberry. This area is markedly free of reed canarygrass due to the established canopy of this willow thicket.

Riparian trees, which provide a root structure that helps maintain stream banks and provides shade for better habitat and to control reed canarygrass, are lacking in Segment 3 of Coe-Clemons Creek. The lack of larger trees, combined with a large sediment loading, has caused the stream to repeatedly changed course and braid.

Restoration Goals and Objectives

The overall goal of the Coe-Clemons Creek Segment 3 restoration project is to improve and allow for fish migration to upstream reaches by reestablishing a single accessible channel within this stream segment and to minimize sediment deposition in the culvert and upper reaches of Segment 3 (Figure 9).

From a sustainable habitat perspective, the best long-term solution to minimize sediment deposition at the culvert and in the upper reach of Segment 3 is to replace the culvert with either a new culvert or bridge. These options are likely cost prohibitive and may not be viable options for the City of Duvall without assistance and cooperation from state and federal agencies. An immediate solution to the sedimentation problem at the culvert is to dredge the culvert. However, without controlling the increased sediment loading from Segment 4 and without the installation of grade controls and the manipulation of the creek's sediment transport capacity immediately upstream and downstream of the culvert, periodic maintenance dredging would be required to remove sediments. Given the condition of the culvert, this report emphasizes the most effective solution to address the immediate risks of a blockage of the culvert including dredging and grade control modifications to Coe-Clemons Creek.

Restoration Goal 1: Provide fish habitat and improve fish access through Segment 3.

Objective 1: Reduce sediment deposition in the stream channel and wetland.

Action: The main sediment source is from Segment 4 upstream of the SR 203 culvert. In order to minimize aggradation, the highest priority action item should be to control the sediment source in Segment 4 before any restoration is performed in Segment 3.

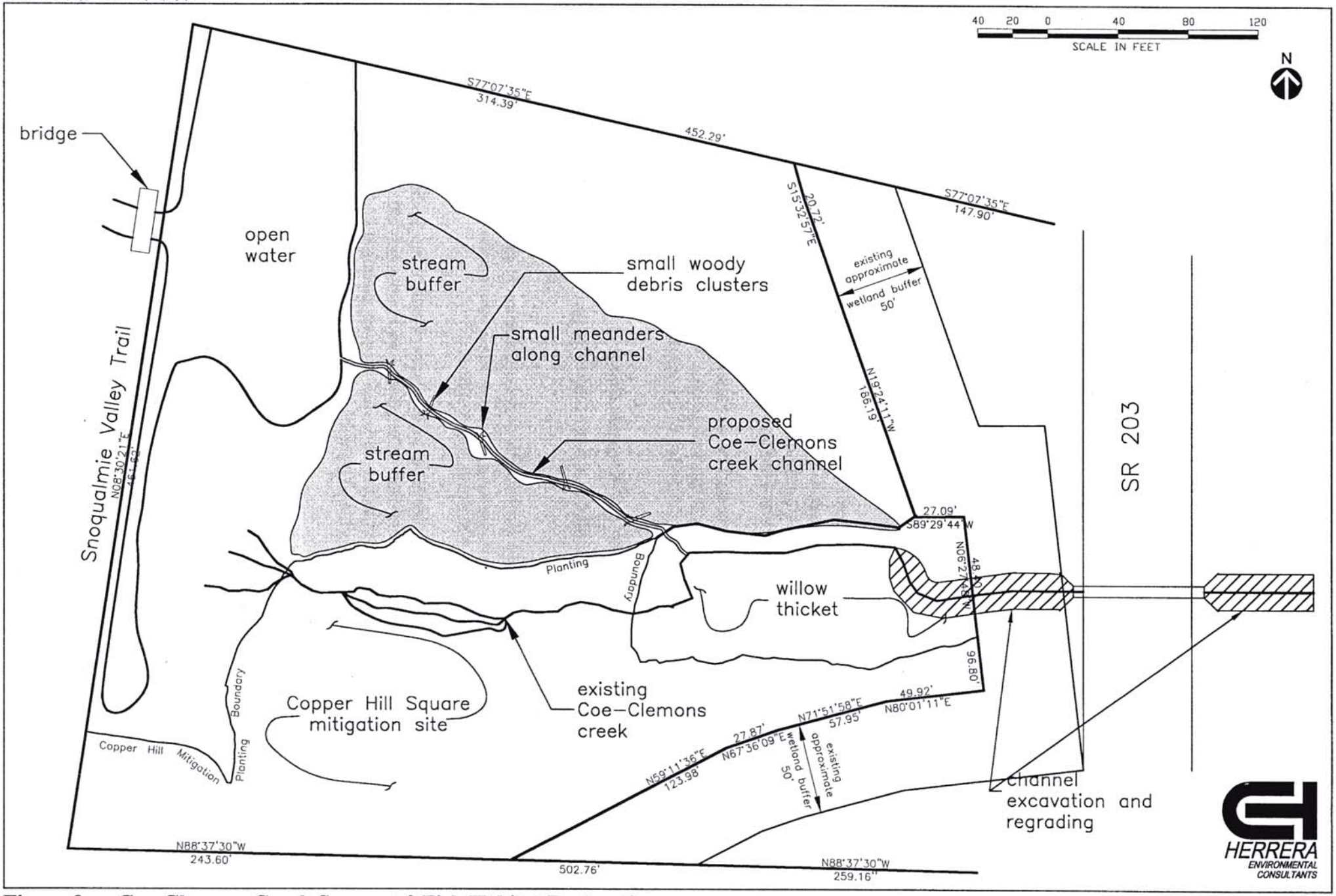


Figure 9. Coe-Clemons Creek Segment 3 Fish Habitat Restoratio

Action: Reed canarygrass, growing in the stream channel and wetlands adjacent to the stream, traps sediment that is transported into this stream segment. In order to prevent aggradation of fine sediment in the channel, the reed canarygrass should be removed.

Action: The stream alignment should be revised to take the most direct route between the edge of the willow thicket and the open water adjacent to the bridge. This direct route will increase the stream's gradient and encourage the flushing of fine sediment through the stream channel.

Objective 2: Create fish habitat in Segment 3.

Action: Streambed gravels appropriate for spawning material and large woody debris clusters will be placed in the newly created channel.

Action: Excavated soil removed from the proposed stream locations will be used to create slightly higher elevation wetland areas for the establishment of native evergreen trees. These trees will provide the recruitment of high-quality large woody debris over the long term of the project.

Performance Standard: There will be an established open stream channel between the open water area near the Snoqualmie Valley Trail bridge to the edge of the willow thicket on the eastern edge of the project site.

Restoration Goal 2: Dredge Culvert and Re-grade Channel.

Objective 1: Conduct a detailed analysis of the existing culvert to prepare final restoration design.

Action: Conduct a detailed professional survey to document existing culvert conditions, invert elevations, existing sediment depth, and stream gradient conditions upstream and downstream of the culvert.

Action: Perform hydrologic modeling to determine whether the gradient is sufficient to minimize sedimentation in Segment 3 and in the culvert. The hydrologic model will be used to develop a sediment aggradation and transport capacity analysis at the culvert, and immediately upstream and downstream of the culvert.

Action: Prepare a stream design for culvert and Segment 3 to link with geomorphic conditions and sediment transport with Segment 4.

Objective 2: Re-grade channel and install grade control structures.

Action: Excavate channel downgradient and upgradient of culvert to lower channel bottom based on design.

Action: Construct grade control structures to maintain consistent grades throughout the stream to minimize aggradation from the culvert through the Copper Hill Square wetland mitigation site. Grade control will include small log and rock structures to decrease the effective streambed grade upgradient of the culvert and increase the gradient through the culvert and into the lower reaches of Segment 3. This increases the sediment transport capacity of the stream as it approaches the culvert, minimizing sedimentation.

Objective 3: Dredge culvert. The culvert should not be dredged before the stream grade is adjusted otherwise the culvert will fill back up with sediment.

Action: Perform feasibility analysis to determine most effective method to dredge culvert while minimizing impacts to the stream.

Action: Divert stream around the culvert by pumping stream over SR 203.

Action: Dredge culvert to match new channel. One dredging option would be to use bucket drag line dredging. This option would consist of floating a cable from one side of the culvert to the other, using a winch or drag line to drag a bucket dredge through the culvert, emptying the bucket into a skiff, then raising the skiff out of the hole with an excavator. A large excavator could be used to lower the dredging equipment to the proper location. It may also be necessary to build a temporary access road to the creek on the upstream side of the culvert. Using a vactor truck to vactor off the uppermost sediment may be necessary to accommodate larger buckets.

Performance Standard: Stabilization of stream dynamics and minimization of sediment deposition in vicinity of culvert to provide at least 2 vertical feet of capacity within the culvert.

Construction

The fish habitat restoration project within Segment 3 of Coe-Clemons Creek will consist of the following three elements:

New Stream Construction in Lower Coe-Clemons Creek

Approximately 165 feet of new stream channel will be excavated to improve fish habitat and decrease sediment aggradation. Approximately 0.75 acres of riparian buffer will be restored. The new stream channel will take the most direct, highest gradient route from the edge of the existing willow thicket to the open water area near the Snoqualmie Valley Trail Bridge.

The challenge for maintaining an open channel through Segment 3 is to decrease the aggradation of fine sediment by eradicating the existing reed canarygrass and establishing a healthy riparian

forest. The existing grass and root mass may be removed by clearing and grubbing; however the seed bank in the soil will remain. Because the seed bank will remain in the soil, two years of maintenance will be performed at the restoration site to reduce the competitiveness of the existing reed canarygrass. Measures taken to control the reed canarygrass could include mowing, or covering with biodegradable material such as cardboard, mulch, or non-woven erosion control fabric.

Willows will be planted densely throughout the restoration area on an average spacing of 3 feet on center. Willows grow aggressively, root densely and compete well with reed canarygrass for nutrients. The dense foliage that willows create cast shade that reduces the ability for reed canarygrass to establish thick mats of roots. In addition, evergreen trees will be planted on an average of 20 feet on center to provide future shade to further reduce the reed canarygrass and to develop a long-term riparian forest.

Grade Control and Excavation Near Culvert

The stream channel upgradient and downgradient of the culvert will be excavated a minimum of 2 feet deep to match the grades of the existing culvert. It is vital to construct the grade control structures before dredging the culvert or sediment will continue to deposit in and around the culvert. Grade control will include a uniform grade approximately 150 feet upstream and downstream of the culvert. The grade will be approximately 1.5 percent. The upstream grade control will consist of wood and rock structures to decrease the effective slope and energy of the channel leading into the culvert. This lower energy slope will better match the characteristics of the channel through the existing culvert and Segment 3, minimizing sedimentation. The mitigation area upgradient of the culvert will require significant excavation, grading, and placement of woody debris to increase sediment capacity.

Culvert Cleaning/Dredging

A thick layer of sediment has collected in the culvert under SR 203. The culvert under SR 203 will likely be cleaned using a cable scoop dredger. The method of dredging should be assessed in a feasibility analysis to determine the most effective method to dredge the culvert while minimizing impacts to the stream. The dredging depth will be determined in the design phase of work based on hydrologic and sediment transport modeling. Dredging will most likely remove at least 2 feet of sediment, which is assumed in the cost estimate.

Cost Estimate

The overall cost of the conceptual fish habitat restoration project for the Coe-Clemons Creek Segment 3 project is expected to be approximately $247,000 (see Table 12). A detailed cost estimate is included in Appendix C. The City of Duvall can decrease the expected cost of the wood structures by stockpiling appropriate wood members for large woody debris prior to the commencement of the public bid process.

Table 12. Coe-Clemons Creek Segment 3 fish habitat restoration plan conceptual cost estimate.

Item	Cost
Design (20% of construction costs)	$ 30,000.00
Permitting (10% of construction costs)	$ 15,000.00
Site Preparation	$ 22,848.90
Earthwork	$ 8,196.60
Streambed Gravels	$ 2,242.50
Wood Structures [a]	$ 7,500.00
Stream Restoration at Culvert	$ 31,100.00
Culvert Dredging	$ 11,190.00
Soils and Permanent Erosion Control	$ 11,903.50
Temporary Irrigation	$ 24,300.00
Plantings	$ 22,039.20
Maintenance – 2 years	$ 11,520.00
Subtotal	$197,840.70
8.6% tax	$ 17,014.30
Subtotal	$214,855.00
15% contingency	$ 32,228.25
Total	**$247,083.26**

This estimate assumes that the project will endeavor to balance cut and fill on the site by backfilling segments of the abandoned channel with fill material removed from the proposed channel. The City of Duvall can decrease the expected cost of the material disposal by providing a nearby location, outside of the 100-year floodplain, to dispose of the excess material.

Coe-Clemons Creek Segment 4

This restoration project on Coe-Clemons Creek is located in Segment 4 within a forested ravine east of SR 203 and west of NE Third Avenue (see Figures 4a and 4b).

Description of Existing Stream Habitat

A summary of the King County Level I stream habitat inventory performed on Coe-Clemons Creek Segment 4 (Herrera 2002) is discussed below. This segment encompasses a landslide area located approximately 1,020 feet upstream of SR 203, where three slides have contributed sediment and large woody debris to the channel. The following description of existing stream

habitat in the area of the slides includes the results of the habitat survey, a description of the riparian soils, substrate, bank stability, channel morphology, large woody debris, pool quality, and riparian vegetation.

Riparian Soils and Substrate

The King County soil survey identifies one soil type in Segment 4 of the Coe-Clemons Creek: Alderwood and Kitsap soils, very steep (USDA 1973). This soil type contains a mixture of Alderwood gravelly sandy loam and Kitsap silt loam soils, which have high erosion and slippage potential.

The channel substrate in the Coe-Clemons Creek Segment 4 consists of small gravel, local deposits of fine sediments, and occasional buried wood debris and boulders. Local accumulations of boulders and logs create a step-pool channel morphology. Where these natural grade control structures are absent, the creek has an incised plane bed. Fine sediment from the slide areas appears to have degraded spawning gravels.

Bank Stability and Channel Morphology

Segment 4, upstream (east) of SR 203, flows through a steep forested ravine. This segment has a gradient of about 9.6 percent and a narrow channel with relatively little floodplain set between steep hillslopes (25 to 35 percent). The ravine is mantled with native vegetation and some large trees (basal diameters >24”). Three notable active landslide sites were observed in reach 58 approximately 1,020 upstream of SR 203 (Figures 4a and 4b, photos 1-4 in Appendix D). The largest slide (No. 3) is located on the south bank and is 243 feet long and 50 feet wide. Slide No. 2 is also on the south bank and slightly smaller. Slide No.1 is located on the north bank and is 50 feet long and 20 feet wide. The three slides have delivered roughly 2,600 cubic yards of sediment into the creek. Slope instability appears to be the result of several factors. The hillslopes are composed of unconsolidated poorly sorted glacial till deposits of silt and sand that are easily eroded. The till is underlain by an impermeable clay unit. Historic forest thinning has reduced the size and density of trees on portions of the ravine’s hillslopes. These unstable conditions are exacerbated by channel incision and bank erosion which undermines the hillslope. Poor drainage from development along the ravine may also be further contributing to hillslope erosion and a distinct septic smell was noted at a small gully running into the southeast corner of slide 3 (Figure 4b, photo 4 in Appendix D).

Where present, the trees have helped to limit adverse impacts of erosion arising from channel adjustment. Trees provide substantial cohesion to unconsolidated soils that can be sufficient to stabilize hillslopes otherwise at risk (Schmidt et al. 2001). If trees are present when a slide does occur, the fallen trees provide another mechanism to limit erosion and create fish habitat. Fallen tree trunks form effective grade control structures that dissipate energy, trap sediment, create pools, and can provide local bank protection (as shown in photo 3 in Appendix D). In this example, a large cedar between slides 2 and 3 is growing on top of a buried log that together have formed an effective revetment limiting bank erosion and preventing the two slides from coalescing (Figure 4b).

Boulders eroded from the glacial till along Segment 4 can also create grade control structures within the creek. Two boulder steps have formed at the upstream end of slide 2. Grade control structures, whether made of logs or boulders, limit the magnitude of incision and landsliding. Each of the three slides in Segment 4 have relatively few trees and sparse stem densities upslope of the slides, indicating that the slides are likely to increase in size and further compound sedimentation at the SR 203 culvert and downstream reaches of Coe-Clemons Creek unless measures are taken to stabilize the sites.

If the slide deposits had remained in place, they would have helped to stabilize the hillslope by forming a toe buttress, but only small quantities, if any, of slide material were found along the creek. Almost all of the slump material delivered to the creek was washed downstream. Till material was clearly apparent in recent deposits within Segment 3. These observations are evidence that Segment 4 has a sediment transport capacity more than sufficient to move most of the sediment it receives. Any restoration actions in Segment 4 should consider actions that would not only stabilize sediment sources, but reduce transport capacity and increase sediment storage within the reach.

Large Woody Debris and Pool Quality

At least 10 logs were observed in the slide area of Segment 4 which consisted of recently fallen deciduous and coniferous trees that are lying unanchored on the banks. This large woody debris is primarily situated above the channel where it provides cover but little in-stream habitat. Only one small pool was observed in the slide area located near the reference cedar between slides 2 and 3 (photo 3 in Appendix D).

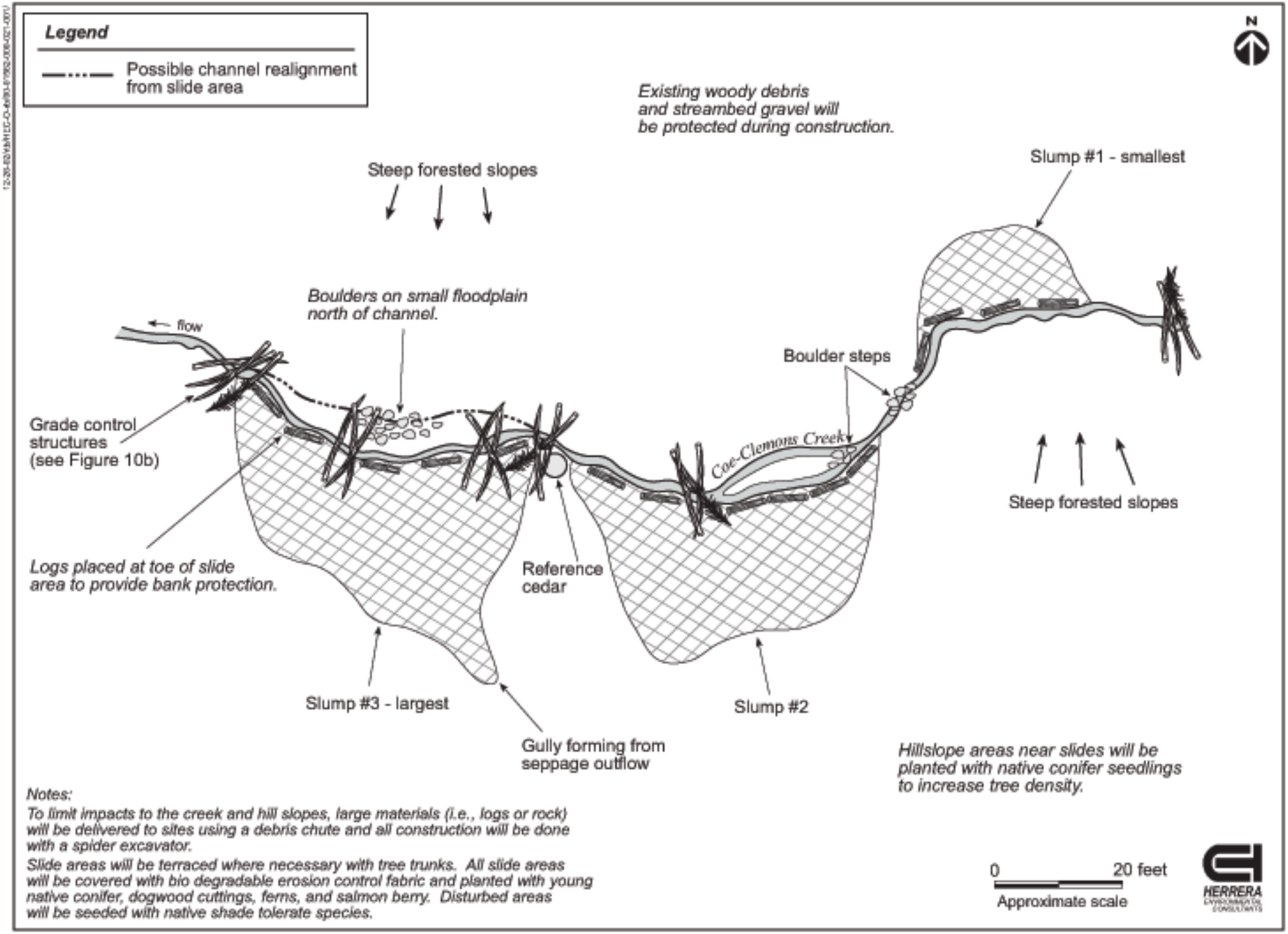
Riparian Vegetation

The width of the riparian zone along the Coe-Clemons Creek Segment 4 slide area is the widest in the watershed. Vegetation throughout the riparian zone is composed of trees, shrubs, and herbaceous species in three canopy layers. Riparian vegetation in the area of the slides consists of a mature mixed forest of red alder, big-leaf maple (*Acer macrophyllum*), western red cedar (*Thuja plicata*), Douglas fir (*Pseudotsuga menziesii*), Himalayan blackberry, vine maple (*Acer circinatum*), Indian plum (*Oemleria cerasiformis*), willow, and salmonberry.

Restoration Goals and Objectives

The overall objective of the Coe-Clemons Segment 4 restoration project is to reduce sediment quantities exported into low-gradient reaches downstream (Figures 10a and 10b). This is accomplished by controlling slides, stabilizing banks, and providing for sediment retention.

Given the geologic conditions within Segment 4, landsliding may continue to occur in Segment 4 of Coe-Clemons Creek. Reforestation and grade control structures that retain sediments and minimize downstream sediment delivery is needed to control the continuing delivery of slide material to the lower stream reaches. Similar interventions as outlined here may be necessary in other portions of Segment 4.



Notes:

To limit impacts to the creek and hill slopes, large materials (i.e., logs or rock) will be delivered to sites using a debris chute and all construction will be done with a spider excavator.

Slide areas will be terraced where necessary with tree trunks. All slide areas will be covered with bio degradable erosion control fabric and planted with young native conifer, dogwood cuttings, ferns, and salmon berry. Disturbed areas will be seeded with native shade tolerate species.

Figure 10a. Coe-Clemons Creek Segment 4 fish habitat restoration plan.

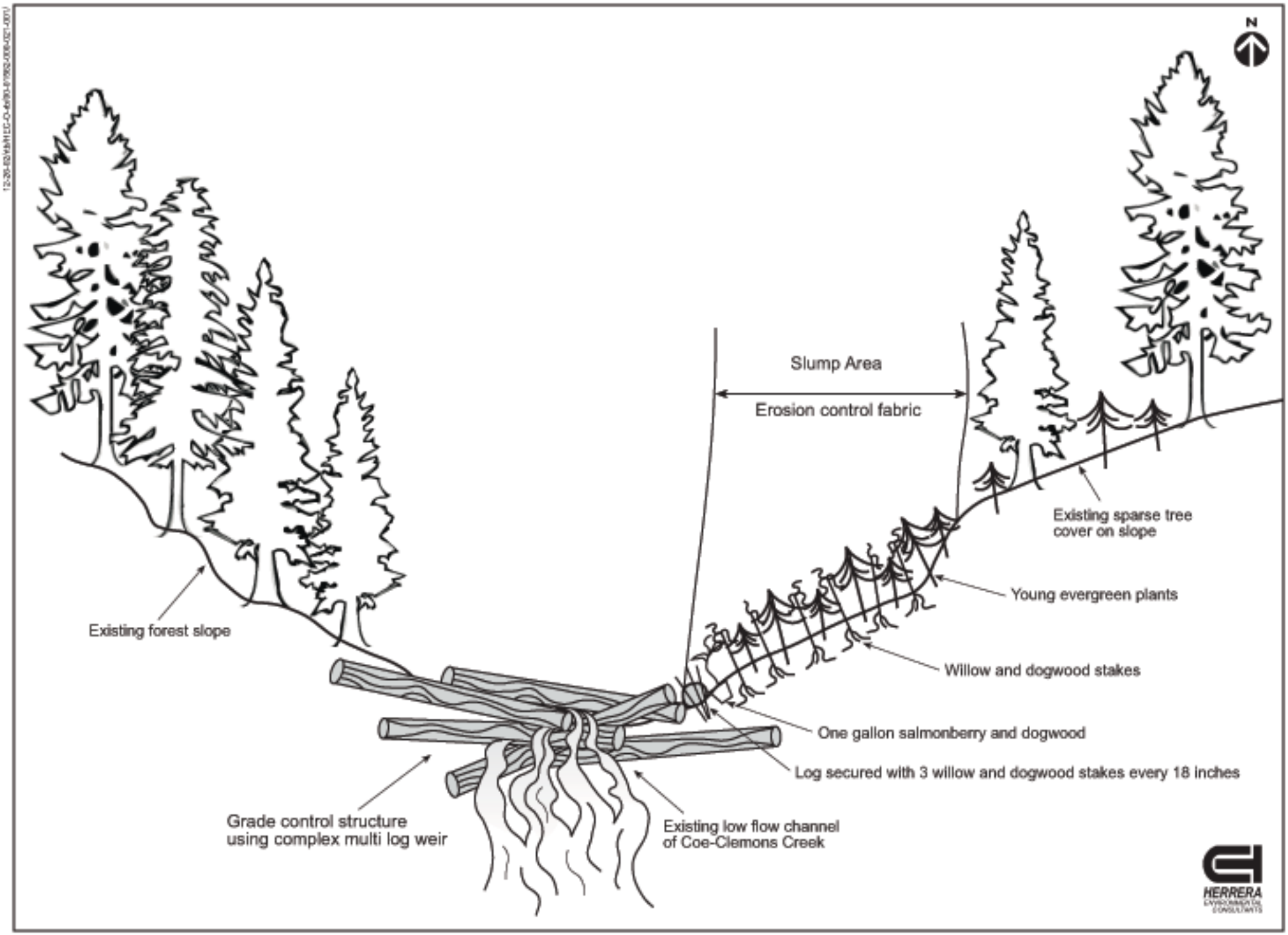


Figure 10b. Cross-section of Coe-Clemons Creek Segment 4 fish habitat

Restoration Goal 1: Reduce sediment supply to downstream reaches of Coe-Clemons Creek.

Objective 1: Protect existing ecosystem through a low-impact construction approach.

Action: All materials installed at the slide locations will be natural materials that are either biodegradable or native plant species. Materials will be transported into the construction site using low-impact methods, such as debris chutes, to minimize disturbance to hillslopes and the creek. Construction and grading will be done with a spider excavator or by hand to minimize disturbance (no access road will be necessary with a spider). All structures will be designed to emulate natural conditions and will blend into the environment (such as complex multi-log weirs). Erosion control practices will be implemented to protect the spawning habitat in the stream. Environmentally sensitive hydraulic fluids will be used in the spider excavator.

Objective 2: Control channel incision and store sediment moving through Segment 4 to enhance aquatic habitat.

Action: Install grade control structures (steps) using complex multi-log weirs or dispersed boulder weirs that emulate natural in-stream structures. Structures will be excavated into valley bottom and toe of hillslopes. Structures will create hydraulic diversity and sediment storage within channel Segment 4. All structures will be designed to ensure fish passage. Construction of these structures will be focused in reach 58 (slide area) and reaches 29-33 upstream of SR 203 culvert. The structures in reaches 29-33 will be constructed to diminish the quantity of sediment reaching the culvert and to improve in-stream habitat. Structures in reach 58 will be integrated into a holistic channel design that includes toe protection described in Objective 3. Temporary flow diversions may be necessary during construction. Excavation and log placement will be done with a spider excavator.

Objective 3: Control erosion along toe of unstable slopes and improve habitat.

Action: Log structures will be buried to armor the toe of unstable hillslopes and to deflect flow away from sensitive areas where possible. Existing roughness elements (i.e., logs and boulders) in the valley bottom that are not enhancing channel conditions within the creek may be re-arranged to improve channel conditions for habitat and fish passage and to protect slide areas. Roughness elements shall be carefully selected for re-arrangement to prevent further destabilization of the creek channel or slopes. Native trees and shrubs will be planted behind the log flow deflectors to provide root cohesion to banks.

Objective 4: Reforest slide areas.

Action: Slide areas will be graded and terraced where necessary to stabilize and prepare slopes for planting. Tree trunks emulating fallen trees will be placed across the slopes where terracing is needed. Erosion control fabric and native grass seed will be placed over the slides. Young conifers, dogwood cuttings, and shrub cuttings will be planted through the weave of the erosion control fabric, without cutting the fabric. Areas with low stem densities located upslope and adjacent to the slides will also be planted with young conifers.

Performance Standard 1: At 5 years, 80 percent coverage of native vegetation will be established in the slide areas.

Performance Standard 2: At 3 years, willow thickets will be established at the toe of each slide.

Construction

The fish habitat restoration for Segment 4 of Coe-Clemons Creek will consist of channel improvements and the stabilization of the three slides adjacent to the channel. Approximately 0.40 acres of surface will be stabilized along reach 58. Channel improvements and improvements to floodplain connectivity may be constructed in reaches 29-33 upstream of SR 203.

Channel improvements will primarily consist of grade control structures (complex steps) constructed of logs or boulders. Snags and logs will be placed on the toe of the slopes to limit bank erosion by the creek.

The slopes of each slide will be stabilized with a combination of localized grading and terracing where necessary, erosion control fabric, tree and ground cover planting, and seeding. Rooted willow and dogwood cuttings and young conifers will be planted through the weave of the erosion control fabric to avoid cutting the fabric.

Care will be taken to protect the existing large woody debris, established vegetation, and stable slopes during construction. Low-impact construction methods will be used such as debris chutes, spider excavators, and minimal disturbance of existing vegetation.

It may be necessary to temporarily divert the streamflow around the construction zone. If this is required, pipes, sand bags, and best management practices will be used to protect the water quality of the stream.

Cost Estimate

Overall cost of the fish habitat restoration project for Coe-Clemons Creek Segment 4 is projected to be approximately $351,000 (see Table 13). A detailed cost estimate is included in Appendix C. The City of Duvall can decrease the expected cost of the slide stabilization by arranging for portions of the restoration work to be performed by community volunteers under the supervision of a qualified wetland biologist.

Table 13. Coe-Clemons Creek Segment 4 fish habitat restoration plan conceptual cost estimate.

Item	Cost
Design (20% of construction costs)	$ 45,000.00
Permitting (10% of construction costs)	$ 22,000.00
Site Preparation	$ 41,550.00
Slope Stabilization (and Grade Control)	$ 92,500.00
Soils and Permanent Erosion Control	$ 38,494.00
Plantings	$ 15,970.00
Temporary Irrigation	$ 8,167.50
Inspection and Maintenance – 2 years	$ 17,280.00
Subtotal	$280,961.50
8.6% tax	$ 24,162.69
Subtotal	$305,124.19
15% contingency	$ 45,768.63
Total	**$350,892.82**

Construction and Post-Construction Management

Construction and post-construction management of stream enhancement and restoration projects is critical to their success. The Washington State Department of Ecology (Ecology) has identified construction oversight, monitoring, maintenance, and contingencies as important elements in the success of environmental projects (Ecology 2002).

Construction Oversight and As-Built Drawings

One of the most significant concerns in the installation of these restoration projects is a lack of appropriate construction oversight. An experienced restoration expert will be included in the construction management team.

Subgrades and final grades will be surveyed to create as-built construction drawings to verify that the grades were constructed as designed.

Monitoring and Maintenance

Regular site maintenance is a crucial component to ensure restoration site success. Site maintenance will include the replacement or adjustment of stressed or dead plants, upkeep of temporary irrigation systems, adjustment of large woody debris or grade control structures, and removal of invasive species as necessary.

Monitoring ensures the ongoing success of the constructed project. The standard monitoring period for most stream restoration projects by Ecology is 5 years. Additional monitoring may be required for areas that are designed to establish forested communities.

Contingency

Mitigation contingency measures are important to the success of habitat restoration projects. Contingency measures will allow for the replacement or enhancement of parts of the project that are failing due to poor construction practices, thus ensuring successful installation of the project. Contingency measures may require a construction bond to cover rectification of construction issues that could potentially cause the restoration project to fail. These corrective actions include the replacement of stressed or dead plant materials, increased duration of temporary irrigation, regrading of inadequately constructed areas, or resetting of destabilized wood debris clusters.

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